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**EXTENDING GENERAL EQUILIBRIUM TO THE TARIFF LINE:  
U.S. DAIRY IN THE DOHA DEVELOPMENT AGENDA**

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# **EXTENDING GENERAL EQUILIBRIUM TO THE TAIRFF LINE: U.S. DAIRY IN THE DOHA DEVELOPMENT AGENDA**

## **Abstract**

We extend general equilibrium (GE) analysis to the “tariff line” by embedding a detailed, partial equilibrium (PE) model of the global dairy sector into a global GE framework. A mixed-complementarity formulation PE model is used to represent bilateral and multilateral dairy trade policy within the broader GE framework with US import protection as our focal point. The impact of liberalizing US dairy imports via bilateral and multilateral tariff-rate quota expansions, out-of-quota tariff cuts, and simultaneous liberalization scenarios is evaluated. We find that the path of liberalization is quite different, depending on the reform approach undertaken. The results have important policy implications for agricultural negotiations in the Doha Development Agenda.

**JEL Codes:** F01, F17, Q17, Q18

**Keywords:** agricultural trade, mixed-complementarity problem, partial equilibrium, general equilibrium, Doha Development Agenda, tariff-rate quotas, WTO

Computable general and partial equilibrium (CGE and CPE) models that quantify the benefits of trade liberalization have become common fixtures in the World Trade Organization's (WTO) Uruguay Round (UR) and Doha Development Agenda (DDA) of trade negotiations (Harrison et al. 1999; Anderson and Martin, 2006; Decreux and Fontangé 2006; Sébastien et al. 2005; Boüet et al. 2005). These models have enriched policy negotiations because (i) they allow for an explicit evaluation of the welfare effects, and (ii) they allow analysts to address the issue of "winners" and "losers" from various reform proposals. Recent CGE and CPE studies find that the world would benefit from trade liberalization, although the aggregate gains have been shrinking and there are losers as well as winners in most scenarios (cf. Anderson and Martin 2006; Anderson Martin and van der Mensbrugghe 2006; Vanzetti and Graham (2002)).

Views on the applicability of CGE and CPE models in the context of the trade negotiations differ widely. Many critics point to the problem of aggregation. During the UR negotiations Sumner (1993) argued that policy models were too aggregated and may have been harmful to the policy debate because they could not accurately represent alternative policy options. Gardner (1993) claimed that CGE models have not necessarily been illuminating because key elements of the proposals dealt with non-standard trade policy instruments that were not well represented in these frameworks.

During the DDA, Bureau and Salvatici (2003) noted that differences in methods of aggregating protection were one of the main reasons why policy results were fundamentally different between diverse models applied to essentially the same set of policy scenarios. Bureau and Salvatici (2003) concluded that "...almost all modeling

efforts of agricultural trade liberalization and market access run into major difficulties (*due to aggregation*) that limit the scope and accuracy of their results” (pg 5).

In light of the fact that disaggregation of trade policy has been strongly advocated since at least 1985 (Anderson), it is puzzling that there has not been a more concerted quantitative effort in this respect.<sup>1</sup> Anderson and Neary (1995) showed how a complex vector of trade policy can be summarized in a single index, called the Trade Restrictiveness Index (TRI). Several variants of the TRI have also emerged such as the Mercantilist TRI (MTRI) (Anderson and Neary 2003) and the expenditure and tariff revenue TRI (Martin 2001). Anderson and Neary (1995) showed how pure quotas can be incorporated into the TRI. In practice however, their measure relies on the quotas being strictly binding and, as we will see, this is not always the case for tariff rate quotas (TRQs) which are pervasive in international dairy trade. Furthermore, TRQs are one of the key vehicles for trade liberalization in agriculture, so effective analysis requires manipulating them at the tariff line.

In this article, we develop a pragmatic solution to the problem of aggregation that is both tractable and readily implemented in standard CGE analyses. Specifically, we develop a highly disaggregated, sub-sector model that handles bilateral and multilateral trade policy at the six digit tariff line using the heavily protected international dairy market as our case study. In addition, this sub-sector model is embedded in a standard CGE model of the global economy and solved using a sequential recalibration technique (Rausch and Rutherford 2007) to provide a comprehensive analysis of trade policy

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<sup>1</sup> For example, the widely used Global Trade Analysis Project (GTAP) aggregates all products and services into just 57 sectors.

reform. Due to the asymmetric treatment of the target sector (dairy), we refer to this as a PE/GE approach to trade policy modeling.

This article is organized in six sections. Section two describes the current state of dairy policy, focusing on the US. Section three introduces the PE/GE modeling framework and the treatment of TRQs. Section four discusses the data. Section five presents our analysis of US dairy reforms and the value of disaggregating trade policy. In the final section we conclude.

### **US Dairy Trade and Protection**

In 2001, US dairy imports amounted to \$1.5 billion dollars and comprised the largest sectoral share of agricultural imports (Nicholson and Bishop 2004). The US was also the world's largest dairy importer. US import data, ranked by value share, for the 24 HS6, and nine HS4 product lines comprising the dairy sector are reported in table 1. The largest class of US dairy imports in 2001 was cheese. Cheese at the HS4 digit level accounted for 59 percent of the total value of dairy imports (column 3). Cheeses are followed in importance by casein, a milk protein concentrate, which accounts for 23.5% of US dairy import values.

At the HS6 digit level, a sharper picture emerges. Over 50 percent of U.S. dairy imports by value are “cheese except 040610-040640 including Cheddar and Colby” (HS6 digit 040690).<sup>2</sup> The European Union (EU), New Zealand, Australia, Argentina and Canada are the world's largest dairy exporters. Together, these countries supplied over 90 (95) percent of U.S. dairy (specialty cheese) imports with EU countries accounting for the largest share.

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<sup>2</sup> Cheese varieties that fall under HS 040690 are Bryndza, Cheddar, Colby, Edam, Gouda, Goya, Romano, Parmesan, Provolone, Sbrinz, Swiss, and cheese substitutes. Herein, we refer to this HS6 product line as specialty cheese.

To better understand what is at stake when it comes to liberalizing US dairy policy, figure 1 summarizes the current levels of ad valorem tariff equivalents and tariff-rate quota protection in the US. The length of the bar depicts the mean applied tariff rate, which is composed of an *ad valorem* tariff and the *ad valorem* equivalent (AVE) of specific tariffs.<sup>3</sup> The U.S. applies specific tariffs on 22 out of 24 tariff lines with an AVE impact ranging from 0 percent to 33 percent. The U.S. applies an *ad valorem* tariff policy on 15 out of 24 dairy commodities ranging from zero to 17 percent. What is notable in figure 1 is that the US has established TRQs on all 18 product lines with higher protection than lactose syrup. This underscores the importance of including this policy instrument in the analysis, especially in international dairy markets.

TRQs were introduced during the UR Agreement on Agriculture (URAA) in instances where tariffs replaced non-tariff barriers (de Gorter and Boughner 1999). Forty-three WTO members have designated TRQs in their tariff schedules for a total of 1,427 individual quotas (Abbott and Morse 2000). While developing countries have not used TRQs extensively, most developed countries opted to convert their NTBs into systems of TRQs, especially in international dairy trade (Abbott and Morse 2000; Meilke et al. 1999).

A review of the economics of TRQs is offered in figure 2. TRQs combine elements of quantitative restrictions (*Quota*) and tariffs ( $t^{in}, t^{out}$ ). With low import demand (*ED*) (regime 1), the TRQ operates as a tariff-only situation shifting the export supply (*ES*) function up by the amount of the in-quota (specific) tariff ( $t^{in}$ ). While tariff revenues are collected on in-quota imports, the quota is not binding and quota rents do not accrue.

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<sup>3</sup> The mean applied tariff rates in figure 1 were calculated using a simple average across all partners for a particular HS6 product line.



In regime 2, import demand is stronger but the (specific) out-of-quota tariff ( $t^{out}$ ) is prohibitive. This is analogous to a pure quota situation where domestic prices are determined by the intersection of  $ED$  and the vertical portion of the  $ES$  function. From the perspective of producers in the exporting nation, regime 2 may be preferable. While the quota restricts supply compared to free trade (FT) or a tariff-only situation (regime 1) the loss in producer surplus resulting from the binding quota may be outweighed by the gain in quota rents (area A).<sup>4</sup> Tariff revenues are collected on all in-quota imports (area B).

When import demand is sufficiently strong as in regime 3, the out-of-quota tariff ( $t^{out}$ ) applies. However, in-quota imports face a much lower tariff rate ( $t^{in}$ ). Thus, the problem arises as to which suppliers are granted the right to supply under the quota since exporters are willing to supply  $Q^I$ , but  $t^{in}$  only applies for in-quota imports. For out-of-quota exporters in regime 3, quota rents are collected on the full difference between the world price and the out-of-quota tariff price times the quota level (area A+B).<sup>5</sup>

In summary, quantitative assessment of dairy policy liberalization confronts a complex situation. First, liberalizing TRQs gives rise to regime changes that shift quota rents which can make a big difference in the welfare impacts of trade reform (de Gorter and Bouhgner 1999). The TRI approach of Anderson and Neary (1995) is not necessarily appropriate because it only applies to imports in regime 2, whereas regimes 1 and 3 are pure tariff regimes. As TRQ liberalization occurs we expect out-of-quota exporters to change regimes which cannot be handled using an aggregate measure of protection.

Second, the model needs to be sufficiently disaggregated, and must be based on bilateral trade, not simply aggregate imports or net trade, as is typical of many PE models

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<sup>4</sup> Quota rents are equal to the difference between the domestic and the tariff inclusive world price multiplied by imports.

<sup>5</sup> The possible choices of administering the quota are numerous and detailed in Skully (1999).

(discussed below). For example, over 90 percent of the US specialty cheese quota is allocated bilaterally by country and variety at the HS8 digit level of commodity aggregation. The remaining quota is allocated multilaterally on a Most Favored Nation (MFN) basis that it is available to any country (AMAD 2001).

### **Previous Studies**

This article is not the first to call attention to the complexity of dairy trade liberalization. A number of important modeling contributions in the presence of TRQs have emerged since the UR. Larivière and Meilke (1999) used a non-spatial, six region PE model of the world dairy trade to analyze the impact of TRQ reform on Canadian, EU and US dairy industries. Market clearing was based on net trade and TRQs were introduced by treating each country's net trade as exogenous (at the quota level) with domestic prices endogenous yielding a domestic price-equivalent of the TRQ policy.

Langley, Somwaru and Normile (2006) estimated the impacts of dairy trade liberalization using the ERS-Penn State Trade model (PEATSim Stout and Abler, 2004) which includes TRQs on dairy and other commodities. The authors found that the quantity of world trade falls (although its value rises) in a global dairy liberalization experiment because higher dairy product prices reduced demand.

Cox et al. (1999) used the UW-Madison World Dairy Model (WDM), a spatial equilibrium model of eight dairy products and 21 regions, to evaluate trade liberalization of world dairy policy including TRQs. The authors found that full trade liberalization had a sizeable impact on domestic milk prices in most OECD countries.

De Gorter and Boughner (1999) provided an excellent economic analysis of TRQs highlighting the importance of understanding the three possible TRQ regimes for

TRQ liberalization. The authors also examined quota fill rates associated with a regulatory requirement such as licensing.

In a CGE context, Elberhi et al. (2004) showed how TRQs can be handled using complementary slackness conditions (Pearson 2002), focusing their attention on sugar trade. Similarly, van der Messenbrugghe and Beghin (vdM-B 2005) illustrated how TRQs can be implemented in the LINKAGE (CGE) model using mixed-complementarity programming also applied to sugar trade.

We adopt a mixed-complementarity framework similar in spirit to vdM-B (2005) and Elberhi et al. (2004). However, what distinguishes our study from theirs, and many others is: (a) the level of disaggregation, (b) the treatment of bilateral trade, and (c) the ability of our framework to embed a detailed sub-sector (PE) model in a standard CGE model thereby allowing for an explicit evaluation of trade policy at the “tariff line” (the PE/GE approach). Elberhi et al. (2004) and vdM-B (2005) focused on sugar trade as this, relatively homogeneous product, is explicitly broken out in the GTAP data base. Both sets of authors carefully avoided dairy trade – despite its much greater importance in world trade and protection – due to the heterogeneity of the sector.

The approach of Larivière and Meilke (1999) and Langley, Smawaru and Normile (2006) did not address bilaterally allocated TRQs nor did they consider partial TRQ liberalization involving regime changes. The WDM used by Cox et al. (1999) allows for product differentiation, and is more disaggregated, however, they used the average quota level and did not address the fact that TRQs vary bilaterally by country and variety (Bureau 1999). Similarly, Cox et al. (1999) avoided partial TRQ reforms and could not identify the specific level of quota expansion required to increase market access.

Stillman (1999) echoed this fact in discussing de Gorter and Boughner (1999): “The economic model for US cheese imports is limited in practice because the US allocates cheese quota by country and variety. *It would be interesting to see an empirical application of dairy products limited by TRQs in the US* to identify what level of quotas and tariffs are necessary to cause an increase in global trade” (p. 5, *italics* added). Our paper fills this gap in the literature on agricultural trade policy modeling.

### **The Disaggregated Sub-Sector Model**

The PE/GE approach builds on a detailed sub-sector dairy model formulated as a mixed-complementarity program (MCP) and subsequently embeds this in the GTAPinGAMS (GE) model (Rutherford 2005). Dairy products are differentiated by country of origin (Armington 1969) and imports from different sources are aggregated into a composite import before substituting for domestic output. Sub-sector dairy products are produced using a constant elasticity of transformation (CET) function that permits dairy capacity to be shifted between HS6 products (e.g. cheese and milk). Indeed, this multi-product industry potentially produces all 24 HS6 products. Sub-sector dairy products are traded and consumed at the HS6 level where they substitute in a constant elasticity of substitution (CES) function. Higher prices encourage more production (via the transformation function) and less consumption (via the substitution function). Aggregate dairy output is governed by the GE model in the same manner as output in other (GE) sectors (Rutherford 2005).

The sub-sector (PE) dairy model is presented in box 1.<sup>6</sup> Subscript  $g$  denotes sub-sector dairy products – defined at the HS6 level;  $i$  ( $d$ ) indexes industry supply (demand)

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<sup>6</sup> Following the GTAPinGAMS model (Rutherford 2005), equilibrium conditions in the dairy sub-sector model are based on a “dual” approach (Dixit and Norman 1992) where zero profits and market clearance,

at the GTAP (GE) level; and  $r$  and  $s$  index source and destination regions respectively. A list of countries and sectors in the PE/GE model is contained in Appendix I.

Equations 1 and 5 in Box 1 determine aggregate dairy output ( $Y_{i,r}$ ) and demand ( $A_{i,d,r}$ ) respectively. These equations are illustrated at the top and bottom of Box 1 because they serve as the link to the GTAP (GE) model (this linkage will be discussed below).  $P_{i,r}^Y$  is the CET unit revenue function that determines the responsiveness of individual product supply to price, where  $\gamma$  is the elasticity of transformation.  $P_{i,d,r}^A$  is the unit expenditure function, determining the responsiveness of dairy product demand at the sub-sector level, where  $\sigma$  is the elasticity of substitution between sub-sector goods ( $g$ ). The solution of the PE model in Box 1 is conditional on the levels of price and sectoral dairy supply ( $p_{i,r}^{ref}, y_{i,r}^{ref}$ ) and demand ( $p_{i,d,r}^{ref}, a_{i,d,r}^{ref}$ ) determined via the GE interactions with the rest of the economy.<sup>7</sup> The parameters  $\varepsilon_s$  ( $\varepsilon_d$ ) are reduced-form supply (demand) elasticities that approximate behavior in the general equilibrium model. By incorporating aggregate industry supply/demand responsiveness to price, convergence of results in the two models is enhanced (see below).

Equation (2) is the market clearing condition ensuring that sub-sector output is sufficient to cover domestic and export demand. This equation determines the supply price of sub-sector goods ( $P_{g,i,r}^Y$ ). The expression on the left-hand side of (2) denotes production activity where,  $X_{g,i,r}^Y$  is the value of sub-sector output and  $P_{i,r}^Y$  is the CET unit

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determine and equilibrium under perfect competition and constant returns to scale. The variables that define equilibrium are activity levels and prices. The “dual” approach is different from standard equilibrium modeling because quantity variables are implicit in the model to determine an equilibrium, but need not appear as explicit variables. This is also the way in which we model TRQs as discussed shortly.

<sup>7</sup> In the benchmark, the reference (ref) prices and quantities are normalized to one. A detailed description of the GTAPinGAMS (GE) model is contained in Rutherford (2005).

revenue function at the industry level. The first expression on the right-hand side of (2) is domestic demand activity where,  $X_{g,i,d,r}^D$  is the level of sub-sector demand,  $t_{i,d,r}^D$  ( $\bar{t}_{i,d,r}^D$ ) is the (benchmark) tax rate on domestic goods and  $\sigma_D$  is the elasticity of substitution between domestic (dairy) goods. The second term on the right-hand side of (2) is the activity level for export demand where,  $X_{g,i,r,s}^{EX}$  is the level of sub-sector bilateral trade,  $M_{g,r,s}$  denotes sub-sector imports into region s and  $\sigma_M$  is the elasticity of substitution between imports from different sources.

Given the importance of specialty cheese (SC) in US imports we introduce several bilateral and one multilateral (MFN) TRQ policy for this tariff line.<sup>8</sup> Dropping subscripts for clarity, tariff-quota activities are based on market clearing equation (3). Exports of SC can be delivered as in-quota trade ( $X^{IQ}$ ) facing a tariff rate ( $t^{in}$ ) and quota rent ( $q^{rent}$ ) in the case of regime 2, as out-of-quota trade ( $X^{OQ}$ ) facing a much higher tariff rate ( $t^{out}$ ) and quota rent ( $q^{rent}$ ) on the in-quota portion of trade, or SC can be delivered by bidding for quota in the MFN market ( $X^{MFN}$ ). Equation (3) is the market clearing condition for tariff quota trade and determines the equilibrium product price ( $P^X$ ) in the destination (US) market.

Equilibrium in tariff-quota trade implies zero profits on exports, after distribution of the quota rents, so we augment the PE trade model with a zero-profit constraint for each tariff quota activity. Following the MCP convention (Rutherford 1995; van der Mensbrugghe 2003), (3.1) specifies the zero-profit condition for in-quota trade ( $X^{IQ}$ ). Specifically, for  $X^{IQ} \geq 0$  to hold with strict *inequality*,  $P^X \leq P^y T^{in} + q^{rent}$  must hold with strict *equality* (i.e., if there are in-quota imports, then quota rents precisely exhaust the

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<sup>8</sup> The data requirements to introduce TRQs are described in the next section.

difference between the domestic price and the tariff-laden import price), where  $T$  denotes the power of trade costs, including taxes/subsidies and transport margins. Analogously, positive out-of-quota trade  $X^{OQ} > 0$  implies that  $P^X \leq P^Y T^{out}$  must hold with strict equality. In this context, there are no quota rents on out-of-quota imports (i.e., once  $X^{IQ}$  hits the quota level denoted  $X^{UP}$ ). Finally, constraint 3.4 dictates that  $q^{rent} > 0$  can only occur if  $X^{IQ} \leq X^{UP}$  holds with strict equality.

The MFN quota is available to any country (AMAD 2001). Thus, it is reasonable to assume that exporters with bilateral SC allocations will want to compete for newly expanded MFN quota. To set up the MFN scenario, we summed all bilateral quotas ( $X^Q$ ), divided by the exporter unit values ( $UV$ ), which yields an MFN quota denominated in physical units (Box 1).<sup>9</sup> MFN quota is allocated via an auction and the highest bids will come from those exporters that supply the highest valued cheeses, and are currently out-of-quota.<sup>10</sup> These countries can bid slightly lower than their bilateral out-of-quota tariff and still garner additional revenue, since they do not have to pay the out-of-quota tariff on the newly expanded MFN quota. Equation (3.3), the zero profit constraint for the MFN quota market, illustrates this point. Notice, the MFN quota rents ( $q^{MFNrent}$ ) are only indexed over the destination country ( $s$ ) (i.e. the US). The existence of a common market for MFN quota implies the existence of a single quota price. For  $X^{MFN} \geq 0$  to hold with strict inequality, profits on MFN trade (destination price ( $P^X$ ) less marginal costs inclusive of the in-quota tariff ( $P^Y T^{in}$ ), scaled by  $UV$ ), must equal the MFN quota revenue collected by the US ( $q^{MFNrent}$ ).

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<sup>9</sup> As discussed in the data section, the MFN quota accounts for roughly 5 percent of the total US specialty cheese quota allocated on a bilateral basis.

<sup>10</sup> In-quota exporters have no incentive to increase supply to a market where marginal cost is already equal to price, less the in-quota tariff.

Equation (4) is the market clearing condition for imports ensuring that the quantity of sub-sector good ( $g$ ) imported is sufficient to cover demand in different markets ( $d$ ), where  $X_{g,i,r}^{AM}$  denotes aggregate expenditure on sub-sector imports,  $X_{g,i,d,r}^{IM}$  denotes import demand,  $t_{i,d,r}^{AM}$  is the tax rate on imports (with benchmark level  $\bar{t}_{i,d,r}^{AM}$ ),  $P_{g,i,r}^M$  is the unit cost of sub-sector imports as a CES function of the destination price ( $P_{g,i,r,s}^X$ ) and  $P_{g,i,d,r}^A$  is the sub-sector Armington price index as a share weighted composite price of domestic ( $\theta^D$ ) and imported ( $\theta^M$ ) sub-sector varieties governed by the import-domestic elasticity of substitution ( $\sigma_{DM}$ ) between sub-sector products.<sup>11</sup>

### Linking PE and GE Models

Our strategy for solving the PE/GE model is based on a decomposition procedure involving sequential recalibration of both PE and GE models (Böhringer and Rutherford 2005; Rausch and Rutherford 2007). Use of this technique is attractive because it permits us to write out the PE model as a separate entity (as in Box 1), thereby clarifying exposition of the modeling framework. Secondly, this PE/GE approach mirrors the way in which much trade policy analysis is conducted. Economists typically start by assessing the economy-wide benefits of a trade agreement using a GE model, thereupon moving down to the PE level as negotiations over sensitive sectors intensify. This PE/GE approach lends itself to that sequence of activities, by permitting the user to readily define industries where sub-sector detail is required. Finally, there is the matter of sheer computational burden. While the incorporation of twenty-four dairy sub-sectors, each

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<sup>11</sup> This is a critical feature of our approach because it implies that imports substitute for domestic products at the HS6 level. In Gohin and Laborde (2006) for example, the authors aggregate imports across HS6 categories before permitting them to substitute for domestic goods. This blunts the impact of heterogeneous tariffs at the HS6 level – effectively eliminating the variation observed in figure 1.



with bilateral trade and inter-industry flows, into the full general equilibrium model would not be computationally prohibitive, this would be an entirely different story if we sought to model all of the food sectors at the tariff line. There are significant computational advantages to partitioning the problem into its PE and GE components.

This is the way the computational strategy proceeds.<sup>12</sup> First, the GE model is calibrated to the levels of industry-wide quantities and prices dictated by the partial equilibrium model (the reference prices and quantities in equations 1 and 5 of Box 1). We then solve the PE model for a new policy regime (e.g., expansion of the bilateral quotas), which, gives rise to new sub-sector prices and quantities and, ultimately, to new levels of aggregate industry demand and supply quantities and prices, as well as industry level tariff-equivalents. The GE model is then recalibrated to replicate this new information, and then it is subsequently re-solved to find the general equilibrium outcome in this new trade policy environment.<sup>13</sup>

With expanded quotas, for example, dairy output in the US will fall as resources leave the sector, and consumption will rise as real incomes rise and prices fall. The size of these changes will inevitably be different from those dictated by the reduced form supply and demand elasticities ( $\epsilon_s$  and  $\epsilon_d$ ), and therefore the PE model will need to be

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<sup>12</sup> See Rausch and Rutherford, 2007, for a more comprehensive exposition in the context of an intertemporal, overlapping generations decomposition.

<sup>13</sup> The experienced GE modeler may initially find the idea of recalibrating preferences and technology objectionable. However, they should be reminded that the recalibrated aggregate dairy preferences over domestic versus imported goods is not the true preference structure, but rather just a convenient approximation to the true preferences over imports and domestic goods. The true preferences that are reflected in the underlying sub-sector model are much more complex and are unchanging over iterations of the sub-sector model.

recalibrated and rerun. This process of iteration is repeated until the two models converge on a common set of price/quantity pairs for all industry variables.<sup>14</sup>

## Data

In this section we describe the data to complete the PE/GE model. The sub-sector dairy model is embedded within the GTAPinGAMS model so it was necessary for the two models to be reconciled. Thereafter, bilateral and multilateral TRQs were incorporated in the sub-sector model on US specialty cheese imports. We discuss each of these in turn.

### *Reconciling Sub-Sector and GTAP Models*

Trade flows and trade policy at the HS6 level were taken from the Market Access Maps (MAcMap) dataset (Bouët et al. 2004).<sup>15</sup> The GE model is based on version 6 of the GTAP data set (Dimaranan and McDougall, 2006) which uses MAcMap for its protection rates. However, GTAP trade data are compiled by Mark Gehlhar (2006), whereas MAcMap bilateral trade data come from the CEPII's BACI data base.<sup>16</sup> For this reason, we reconciled the international dairy flows as follows. First, intra-EU dairy trade was eliminated from GTAP trade flows.<sup>17</sup> Second, the sub-sector dairy data was scaled so that both PE and GE models agree on sectoral level dairy trade between partner countries.

Statistics on domestic production, demand and prices are generally not available at the HS6 level of commodity detail. However, we do have sectoral level data on

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<sup>14</sup> Our experience shows that this convergence is extremely rapid, requiring less than 5 iterations. The full GAMS code for implementing the PE/GE model is available from the authors upon request. Note that our analysis offers a means of quantifying aggregation errors in conventional GTAP (GE) analyses of policy liberalization by comparing our PE/GE model to the standard GTAP (GE) model that does not include a detailed sub-sector model. We do not address aggregation errors here but is a topic in another paper of the authors.

<sup>15</sup> MAcMap has been developed jointly by the International Trade Center in Geneva (ITC) and Paris-based CEPII and includes an exhaustive list of applied and bound *ad valorem* and specific tariffs, indicators of TRQs and TRQ rents, as well as taking into account an extensive list of tariff preferences ([www.cepii.com](http://www.cepii.com)).

<sup>16</sup> BACI is CEPII's analytical database for international trade flows ([www.cepii.com](http://www.cepii.com)).

<sup>17</sup> Intra-EU trade flows are not available in CEPII's sub-sector level trade data, so we prefer to eliminate intra-EU trade at the GE level, rather than trying to create sub-sector trade flows in some arbitrary manner.

domestic dairy supply and demand from the GTAP model. Sub-sector domestic supply and demand were obtained by estimating sub-sector demand using a constrained optimization approach. Sub-sector supply was obtained as a residual. Details are provided in appendix II. While we recognize this is an imperfect characterization of the dairy sector, what distinguishes our approach is the fact that imports can compete with domestic dairy products at the “tariff line”. Until domestic data become available at this level of detail, our approach provides a reasonable starting point and is consistent with sectoral demand and supply data used in the GTAP model.

There are four parameters in the sub-sector dairy model. We adopt the estimate of the import-import substitution elasticity ( $\sigma_M = 7.3$ ) reported by Hertel et al. (2007) based on a cross-section, econometric model featuring detailed trade cost data and import sourcing patterns in the US and other countries. Following the “rule of two”, this is assumed to be twice as large as the import-domestic elasticity ( $\sigma_{DM} = 3.65$ ).<sup>18</sup> These are clearly the most important parameters in this modeling exercise, as they determine the degree to which policy shocks will affect trade flows within the dairy industry.<sup>19</sup>

In addition to the Armington parameters, there are two other elasticities in the dairy model. The elasticity of transformation ( $\gamma$ ) governs the ease with which dairy output can be transformed amongst 24 different sub-sector products. Because dairy products share the same input – fluid milk – we are inclined to believe that this transformation

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<sup>18</sup> It is hard to find good estimates of  $\sigma_{DM}$  since this requires combining trade data with data on domestic utilization. The idea of setting  $\sigma_{DM}$  equal to one-half  $\sigma_M$  dates back to Jomini et al. (1991). It has subsequently been subjected to econometric testing in the context of a global GE model by Liu et al. (2004), who failed to reject this hypothesis.

<sup>19</sup> The estimates in Hertel et al. (2007) are based on comparably disaggregated trade data used here. However, in that study the Armington parameter was constrained to be equal for all product lines within the dairy sector. We recognize that its value likely varies considerably between relatively homogeneous products such as skim milk powder, and more differentiated products, such as cheese. Future econometric work should address this limitation.

elasticity should be quite large, in absolute value, and set it equal to 4.0. The other parameter required in the PE model is the elasticity of substitution ( $\sigma_D$ ) in consumption between dairy sub-sector products, once these have been aggregated across sources. How responsive are consumers to price when choosing among different types of cheeses, or between fresh milk and yogurt products? While this substitutability is surely larger than that between dairy products as a group and other food items, we are inclined to believe this is not nearly as large, in absolute value, as the transformation elasticity. So we set it equal to 1.0, and sub-sector supply is much more elastic than demand, at the product level.<sup>20</sup> Given the uncertainty associated with these two elasticities, we have conducted considerable sensitivity analysis with respect to their values. The impacts of US trade policy appear to be quite robust to variation in these parameters (i.e., cutting by half and doubling their values).

#### *US Bilateral Tariff-Quota Data*

The US has *nine* different SC quotas (called TRQIDs) totaling over 136,000 metric tons (mt). Within each TRQID, the quota allocated varies by country and variety across product lines at the HS8 digit level (AMAD 2001). However, each TRQID covers a subset of HS8 digit cheese lines that do not necessarily map directly to the sub-sector's HS6 SC line (i.e. HS 040690). Table 2 reports the value (V) and quantity (Q) share of SC trade (HS 040690) under each TRQID. In most cases SC accounts for more than 90 percent of trade – the exceptions being TRQID 12 and 17 which are varieties of Blue Veined and Swiss cheese. Thus, although we do not consider separate TRQs for each TRQID, our results are quite realistic given the importance of SC in US dairy TRQs.

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<sup>20</sup> Our PE model does not require an elasticity of transformation between domestic sales and exports. This is assumed to be infinite, matching our assumption in the standard GTAP model.

We also had to confront the issue of bilateral quota allocations. The AMAD notifications report the quota level allocated to specific partners for each TRQID. However, not all countries export to the US in all TRQID categories (table 2). Furthermore, for some TRQIDs (but not all) Finland, Sweden and Austria received separate quota allocations from the EU15 as a group. To minimize the amount of information lost in aggregating TRQs to the PE/GE model's HS6 digit commodity level and 14 country aggregation, we calculated the filling ratios for each of the nine US SC quotas at the most detailed level available (HS8 digit) as follows,

$$(6) \quad {}^{ID}FR_{r,k} = \frac{{}^{ID}Quant_{r,US,k}}{{}^{ID}Quota_{r,k}}$$

where,  $ID$  indexes a particular TRQID ( $ID = 11 \dots 19$ ),  $r$  indexes the source region,  $k$  indexes the HS8 digit specialty cheese line,  $FR$  denotes the filling ratio, equal to the quantity exported from  $r$  to the US ( $Quant$ ) divided by the  $Quota$  allocated to  $r$  in commodity ( $k$ ) and TRQID ( $ID$ ). At this point we have filling ratios at the HS8 digit level that vary by  $r$  and  $ID$ .

Next we aggregated the filling ratios under each TRQID to the sub-sector model regions (14 countries) using a trade-value weighted aggregation as,

$$(7) \quad {}^{ID}FR1_m = \sum_m \left[ \frac{{}^{ID}V_{r \in m, US, k \in g}}{\sum_m {}^{ID}V_{m, US, k \in g}} {}^{ID}FR_{r,k} \right]$$

where,  $m$  indexes one of the 14 PE/GE model countries in a particular TRQID ( $ID$ ). The numerator in (7),  ${}^{ID}V_{r \in m, US, k \in ID}$ , is the value of trade from  $r$  (as an element of  $m$ ) to the US in commodity  $k$  (as an element of TRQID ( $ID$ )) and the denominator is the total value of

trade from  $m$  to the US in a particular TRQID. This yields a value share from which to weight the filling ratios ( $FR_{r,k}$ ) derived in (6).

The share weighted filling ratios ( ${}^gFR_m$ ) in (7) vary by TRQID ( $g$ ) and PE/GE model countries ( $m$ ). As a final step we aggregated  ${}^{ID}FRI_m$  across TRQIDs using the value of trade in the total value of trade across all TRQIDs as weights to arrive at the model aggregated filling ratios which vary only by ( $m$ ):

$$(8) \quad FR2_m = \sum_m \left[ \frac{V_{m,US,g}}{\sum_g V_{m,US,g}} FR1_{m,g} \right]$$

The resulting filling ratios from equations (7) and (8) are reported in table 3. The EU15 is the only country to trade in all nine TRQIDs. TRQID 11 (Cheese Substitutes) is the largest traded category with the EU15 and NZL getting the largest quota allocation in this category. The final column in table 3 reports the PE/GE model filling ratios.

Interestingly, six countries were out-of-quota in 2001 with Australia (AUS) exporting more than twice its quota allocation. Clearly these seven countries have a lot at stake when it comes to liberalizing US specialty cheese TRQs.

#### *US Multilateral (MFN) TRQs*

To complicate matters further, the MFN quota, which is available for any country, is yet another component of the US specialty cheese TRQ policy. It is also being discussed as a modality option in the DDA.<sup>21</sup> As table 3 reports, the MFN quota accounts for less than five percent of bilateral SC TRQS in most cases. We allocate the MFN quota as an auction where the quota goes to the highest bidder and assume that exporters

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<sup>21</sup> The CAIRNS group of exporting countries and the G-33 group of developing countries have pushed for substantial increases in market access in this respect. Indeed many countries would like to see the bilateral quota allocations (i.e. US dairy) removed.

can shift SC from the bilateral out-of-quota market to the MFN market costlessly. This is an important point because substantial improvements in market access may not occur immediately if exporters simply redirect bilateral (out-of-quota) exports to the MFN regime in order to take advantage of the additional revenue available.

Which exporter will pick up the MFN quota is a critical issue in the set up of this scenario. We resolved this by incorporating detailed unit values of specialty cheese supplied by different exporters to re-establish the units of comparison.<sup>22</sup> As table 3 reports, the EU15 supplies the highest valued specialty cheese so we normalize all unit values on the (0,1) interval ( $EU15 = 1.0$ ).

## **Results**

Four liberalization experiments were performed to illustrate the flexibility and usefulness of our PE/GE framework and the treatment of TRQs in the context of the DDA negotiations. Scenario 1 progressively liberalizes US TRQs by expanding bilateral quota levels. Scenario 2 liberalizes the TRQ policy by progressively cutting out-of-quota tariffs. Scenario 3 liberalizes TRQs by simultaneously expanding (cutting) the quota (out-of-quota tariff). Finally, in scenario 4 we expand the MFN quota. All experiments progressively liberalize TRQs until complete (100%) liberalization is achieved.

Figure 3 reports the evolution of out-of-quota and in-quota imports and tariff quota rents for New Zealand (NZL), Canada (CAN), Australia (AUS), the EU-15 members (EU15) and Rest of Europe (ROE) in the case of in-quota imports after progressively expanding all bilateral quotas (scenario 1) in 10 percent increments (other exporters are suppressed for ease of exposition). What is notable in figure 3 is that small quota expansions less than 30 percent, as may be agreed too under a modest DDA

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<sup>22</sup> We draw on the CEPII data base which estimates unit values by exporter.

scenario, may not result in significant improvements in market access. This is because the major exporters of specialty cheese are substantially out-of-quota (regime 3).

Looking at out-of-quota imports, for the EU and CAN (AUS and NZL) to move out of regime 3, the DDA would have to agree on a 30 (40) percent quota expansion. Until exporters move out of regime 3 and into regime 2, there is no price decline and hence no increase in imports.

In-quota imports are shown in the middle panel of figure 3. Here we have suppressed AUS and added the Rest of Europe (ROE) whose exports are not out-of-quota in the benchmark. This figure illustrates an important point regarding in-quota exporters. Once the EU15 and CAN move into regime 2 (30% quota expansion), ROE imports begin to decrease as the US substitutes towards lower priced imports from the EU15 and CAN. After a 40 percent quota expansion, AUS and NZL enter regime 2 and ROE imports are largely displaced. In the benchmark, US imports of ROE specialty cheese totaled almost \$0.14 million before falling sharply to \$0.01 million when all quota constrained countries entered regime 1.

The final panel in figure 3 tracks the level of bilateral tariff quota rents which accrue to the exporting country. Modest quota expansions (<30%) actually increase quota rents for all out-of-quota exporters, as the volume of in-quota export earning quota rents increases. For example, quota expansions greater than 30 percent moved the EU15 and CAN into regime 2 where quota rents dissipate quickly. AUS and NZL quota rents increase as long they remain in regime 3 (until a 40 percent expansion is reached). Note that a 70 percent US specialty cheese bilateral quota expansion is necessary for all quotas to become non-binding (i.e., they are all in regime 1).



Being able to track the path of TRQ rents has important policy implications in the context of the DDA. Our analysis suggests dairy exporting countries may support small expansions in the US specialty cheese quota because quota rents increase initially. However, exporters may not be enthusiastic supporters of bilateral quota expansions greater than 40 percent in the DDA because of the sharp decline in quota rents when all countries enter regime 2.

How does this compare with other approaches to liberalizing dairy TRQs? In table 4 we compare market access opportunities by reporting aggregate import volume and (after tariff) price changes for all four liberalization scenarios. Note that each scenario in table 4 reports increments of liberalization (versus 1an absolute 10 percent quota expansion in figure 3 for example). That is, scenario 1 (bilateral quota expansion) required a 190 percent expansion to achieve 100 percent liberalization. Thus, each 10 percent bilateral quota liberalization increment in table 4 is equivalent to a 19 percent bilateral quota expansion (see footnote to table 4).

Consistent with our previous discussion, expanding the quota (scenario 1) does not generate substantial market access until out-of-quota exporting countries move out of regime 3. For example, when all bilateral quotas are expanded by 76 percent (40% liberalization), aggregate imports increase by 30 percent with the composite import price decreasing by 7.19 percent. On the other hand, reductions in the out-of-quota tariffs increase market access almost immediately (scenario 2). If the the DDA could agree on a 20 percent out-of-quota tariff cut it would generate an increase in market access equivalent to a 76 percent quota expansion (compare scenarios 1 and 2). Moreover, simultaneously liberalizing the quota and out-of-quota tariff produced similar results to

cutting out-of-quota tariffs alone (scenario 3). This important result is driven by the fact that tariff cuts contributed to lower prices even as exporters remaining in regime 3.<sup>23</sup>

In the final scenario (scenario 4, table 5) we progressively expand the MFN quota. Recall, the MFN quota represents approximately 5 percent of total bilateral quotas in the specialty cheese market (table 3). Thus, our liberalization experiment introduces MFN quota in increments of five percent of total bilateral quotas (i.e.  $0.05 * X^{MFN}$  in Box 1).

The highest unit values for specialty cheese exports belong to the EU15 and CAN, which are therefore the highest bidders for the MFN quota at the outset. What is interesting about this scenario is the EU15 and CAN begin by simply diverting (bilateral) out-of-quota exports to the MFN quota market. That is, out-of-quota exporters exhibit a horizontal supply function as long as there are still out-of-quota bilateral exports to be diverted to the MFN market. This is a key insight offered by our paper. Compared to out-of-quota tariff cuts, very little liberalization occurs with 10 and 20 percent MFN expansion as exporters simply divert their out-of-quota bilateral exports to the MFN market. Thereafter, liberalization increases quickly. After a 30 percent expansion the EU15 and CAN have exhausted the transfer of bilateral out-of-quota exports and AUS and NZL are in the bidding for MFN quota. In terms of increased market access, a 40 percent MFN quota expansion actually generates a larger increase (decrease) in imports (price) than out-of-quota tariff cuts. Remarkably, complete liberalization (a 273 percent increase in imports equivalent to a 190% bilateral quota expansion) occurs after MFN quota is expanded by only 50 percent of the amount required for full liberalization under the bilateral expansion scenario.

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<sup>23</sup> We also tracked bilateral quota rents in the out-of-quota tariff cutting scenario and found that liberalizing in this way cut immediately into quota rents. The results are available from the authors upon request.

## **Conclusion**

Agricultural market access continues to be a contentious issue in the DDA where WTO Members have made it clear that they are unwilling to negotiate on other topics until a suitable agreement on agriculture exists. We develop a pragmatic approach to the problem of policy aggregation in standard CGE analysis. Our PE/GE approach embeds a detailed PE model of international dairy trade within the standard GTAPinGAMS framework. Specifically, we disaggregate dairy into 24, HS6 product lines, focusing special attention on US specialty cheese imports and the associated TRQ policy. This permits us to illustrate how complex trade policies that vary by commodity and country can be handled within a GE framework. We also highlight for the first time the interaction between MFN quota expansions (the proposed negotiating modality under the DDA) and existing bilateral quotas which dominate US dairy imports at present.

Our results contribute to the policy debate by comparing alternative TRQ liberalization options and the extent of TRQ liberalization required to achieve significant import expansion in the US specialty cheese market. Expanding bilateral quota levels under the DDA on the order of 20-30 percent (on an absolute basis) will benefit some exporting countries through higher quota rents but will not generate much in the way of increased trade. Exporting countries that do not face a binding TRQ policy see their bilateral trade with the US being displaced as out-of-quota exporting countries move out of regime 3 and their US price begins to fall.

For small liberalization commitments (<40%), cutting out-of-quota tariffs is clearly the most efficient method of improving market access in the US specialty cheese sector. This result is consistent with de Gorter and Boughner (1999) and Elberhi et al.

(2004) who similarly argued for out-of-quota tariff cuts. However, expanding the MFN quota is the option currently receiving the most attention in the DDA negotiations. Here, there are some very interesting interactions with the bilateral quotas currently in place. MFN quota expansions initially have little impact because exporters simply divert bilateral out-of-quota exports to the MFN market. However, once this transfer is completed, MFN expansion increases trade quite rapidly towards the free trade equilibrium (more than simply expanding the existing bilateral quotas.) Of course eliminating the bilateral quotas and replacing them with MFN quotas would offer a more immediate impact on trade, but it would also likely encounter resistance from current quota-holders who would see their quota rents evaporate immediately upon implementation of such a policy.

In summary, the framework developed in this paper offers an excellent vehicle for conducting trade policy analysis. Researchers can begin their investigations within the standard general equilibrium framework, thereby identifying where the most sensitive outcomes are likely to arise. They can then target a sector for special attention – in this case we focus on the dairy industry. As we have shown in this paper, data bases are now available to support HS-6 level analysis of trade policy – including TRQs. By adopting the PE/GE framework proposed in this paper, economists can finally address the perennial criticism that their analysis is too aggregated. With this framework in hand they can effectively take trade policy “to the tariff line”.

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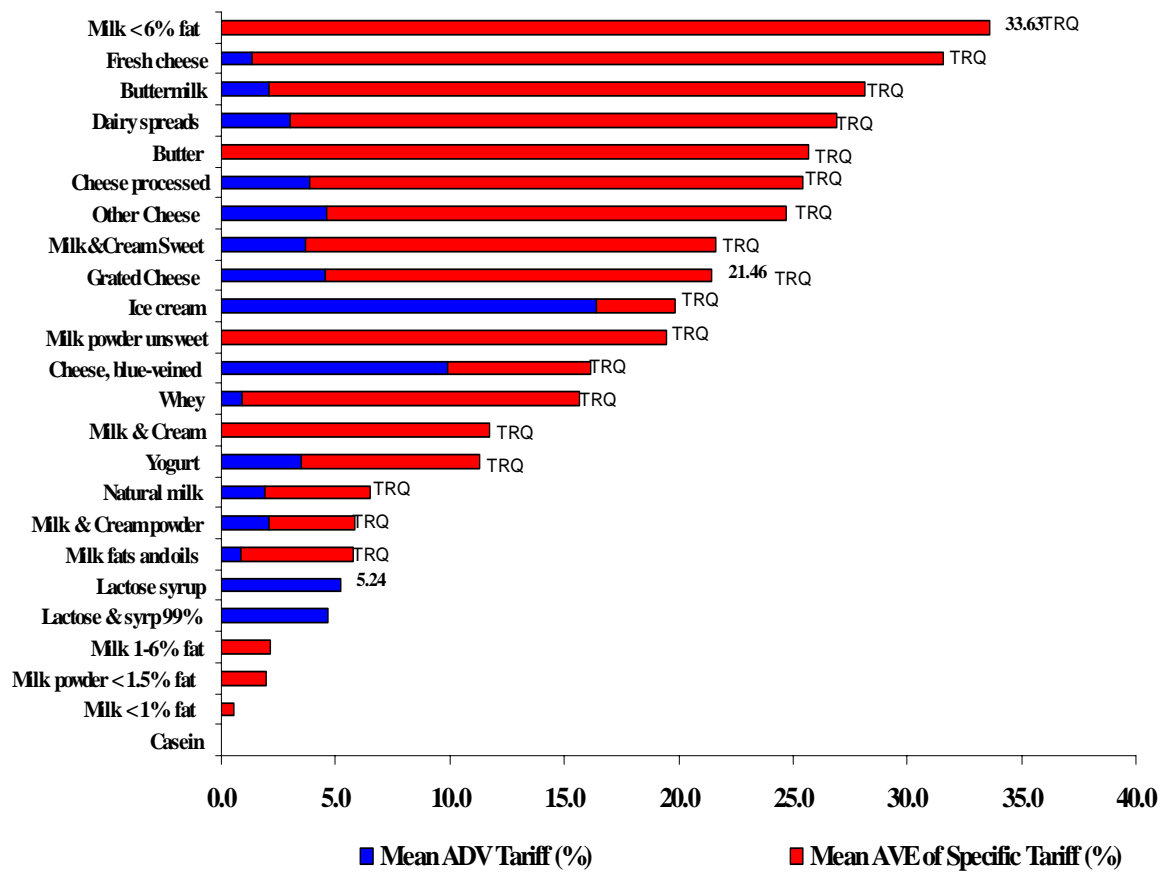
**Table 1. The Composition of U.S. Dairy imports (2001)**

HS6	HS4 Description	HS4 Import Share (%) <sup>a</sup>	HS6 Description	HS6 Import Share (%) <sup>a</sup>
040690			Cheese except 040610-040640 including Cheddar and Colby	52.3
040630			Cheese processed, not grated or powdered	2.2
040640	Cheeses	58.6	Cheese, blue-veined	1.8
040620			Cheese, grated or powdered, of all kinds	1.3
040610			Fresh cheese, unfermented whey cheese, curd	0.9
350110	Casein and milk protein concentrates	23.5	Casein and other caseinates	23.5
040590			Other milk fats and oils	2.4
040510	Butter and dairy spreads	6.1	Butter	2.0
040520			Dairy spreads	1.7
040490			Natural milk products nes	3.4
040410	Whey and modified whey	4.5	Whey and modified whey	1.1
040210			Milk powder < 1.5% fat	1.1
040299			Milk and cream nes sweetened or concentrated	1.1
040221	Milk and cream powders	3.5	Milk and cream powder unsweetened < 1.5% fat	1.0
040291			Milk and cream unsweetened, concentrated	0.2
040229			Milk and cream powder sweetened < 1.5% fat	0.1
210500	Ice Cream	1.6	Ice cream and other edible ice	1.6
040130			Milk/cream not concentrated nor sweetened < 6% fat	0.7
040120	Milk not concentrated nor sweetened	1.1	Milk not concentrated nor sweetened 1-6% fat	0.3
040110			Milk not concentrated nor sweetened < 1% fat	0.1
040310			Yogurt	0.5
040390	Yogurt and buttermilk	0.9	Buttermilk, curdled milk, cream, kephir, etc.	0.4
170211			Lactose & syrup, containing by weight 99 % or more lactose	0.2
170219	Lactose and Lactose Syrup	0.3	Other Lactose and lactose syrup	0.1

<sup>a</sup> Numbers indicate value shares

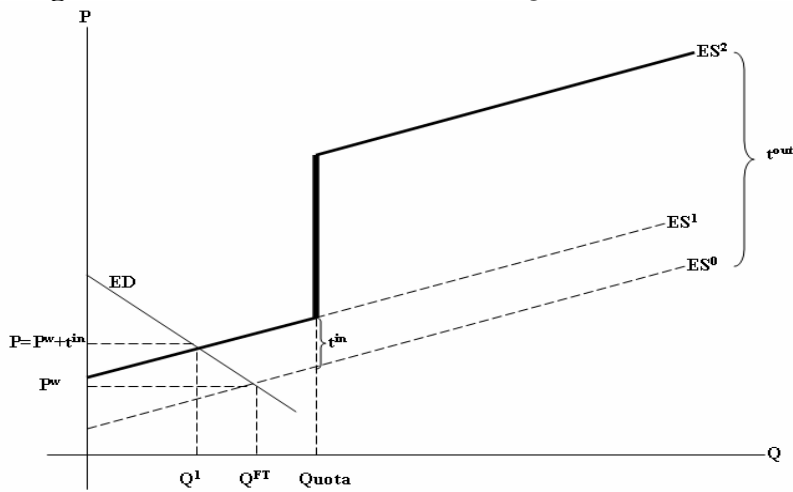
Source: CEPII (2001) and author's calculations

**Figure 1. Import Protection in the U.S. Dairy Market**

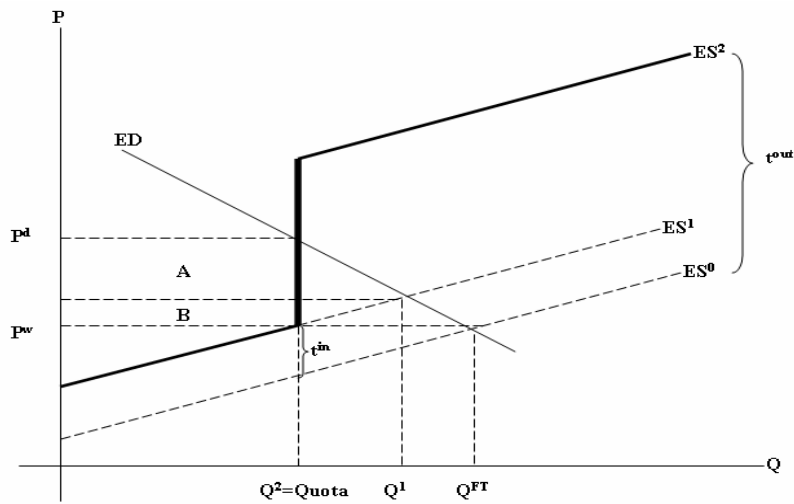


Source: CEPII (2001) and author's calculations

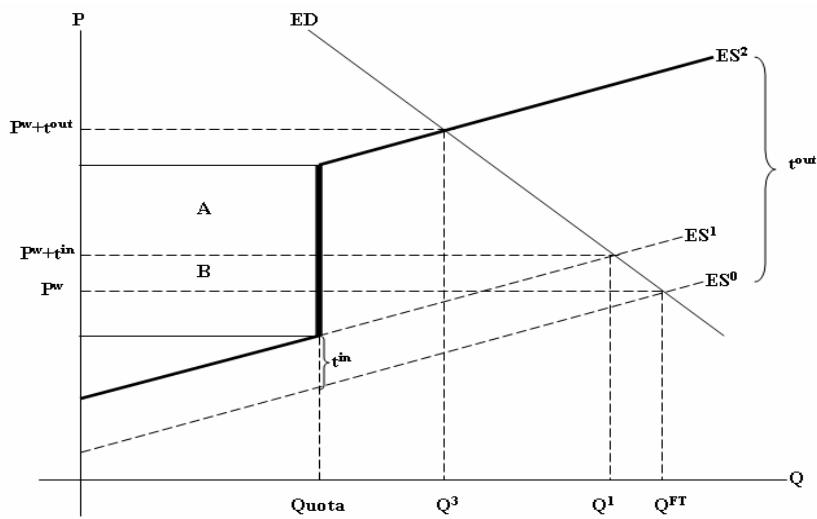
**Figure 2. Economics of Tariff-Rate Quotas**



**Regime 1 – Tariff Only**



**Regime 2 - Pure Quota**



**Regime 3 - Mixed  
Tariff and Quota**

### Box 1. Sub-sector Partial Equilibrium Model Equations

$$1. Y_{i,r} = y_{i,r}^{ref} \left( \frac{P_{i,r}^Y}{P_{i,r}^{Yref}} \right)^{\varepsilon_Y}, \text{ where } P_{i,r}^Y = \left[ \sum_g \left( \theta_{g,i,r}^Y P_{g,i,r}^Y \right)^{1+\gamma} \right]^{\frac{1}{1+\gamma}}$$

$$2. Y_{i,r} \left( \frac{P_{g,i,r}^Y}{P_{i,r}^Y} \right)^\gamma X_{g,i,r}^Y = \underbrace{\sum_d X_{g,i,d,r}^D \left( \frac{P_{g,i,d,r}^A}{P_{g,i,r}^Y} \frac{(1 + \bar{t}_{i,d,r}^{AD})}{(1 + t_{i,d,r}^{AD})} \right)^{\sigma_D} \left( \frac{P_{i,d,r}^A}{P_{g,i,d,r}^A} \right)^\sigma A_{i,d,r}}_{DOMESTIC} + \underbrace{\sum_s X_{g,i,r,s}^{EX} \left( \frac{P_{g,i,s}^M}{P_{g,i,r,s}^X} \right)^{\sigma_M} M_{g,i,s}}_{EXPORT}$$

$$3. X_{SC,i,r,s}^{IQ} + X_{SC,i,r,s}^{OQ} + X_{SC,i,r,s}^{MFN} = X_{SC,i,r,s}^{EX} \left( \frac{P_{SC,i,r,s}^M}{P_{SC,i,r,s}^X} \right)^{\sigma_M} \left\{ \begin{array}{l} (3.1) \quad X_{SC,i,r,s}^{IQ} \geq 0 \quad \perp \quad P_{SC,i,r,s}^X - P_{SC,i,r}^Y T_{g,i,r,s}^{in} - q_{g,i,r}^{rent} \leq 0 \\ (3.2) \quad X_{SC,i,r,s}^{OQ} \geq 0 \quad \perp \quad P_{SC,i,r,s}^X - P_{SC,i,r}^Y T_{g,i,r,s}^{out} - q_{g,i,r}^{rent} \leq 0 \\ (3.3) \quad X_{SC,i,r,s}^{MFN} \geq 0 \quad \perp \quad UV_{g,i,r} (P_{SC,i,r,s}^X - P_{SC,i,r}^Y T_{g,i,r,s}^{in}) \leq q_{g,i,s}^{MFNrent} \\ (3.4) \quad q_{g,i,r}^{rent} \geq 0 \quad \perp \quad X_{SC,i,r,s}^{IQ} \leq X_{SC,i,r,s}^{UP} \end{array} \right.$$

Where,

$$X_{SC,i,r,s}^{MFN} = \sum_r \frac{X_{SC,i,r,s}^Q}{UV_{SC,i,r}} \text{ (and } X_{SC,i,r,s}^{MFN} = 0 \text{ in the benchmark equilibrium)}$$

$$4. M_{g,i,r} X_{g,i,r}^{AM} = \sum_d X_{g,i,d,r}^{IM} \left( \frac{P_{g,i,d,r}^A (1 + \bar{t}_{i,d,r}^{AM})}{P_{g,i,r}^M (1 + t_{i,d,r}^{AM})} \right)^{\sigma_M} \left( \frac{P_{i,d,r}^A}{P_{g,i,d,r}^A} \right)^\sigma A_{i,d,r}$$

where,

$$P_{g,i,r}^M = \left[ \sum_g \left( \theta_{g,i,r}^M P_{g,i,r}^{Xss} \right)^{1-\sigma_M} \right]^{\frac{1}{1-\sigma_M}}$$

$$P_{g,i,d,r}^A = \left\{ \underbrace{\theta_{g,i,d,r}^{Dss} \left( \frac{P_{g,i,r}^{Yss} (1 + t_{i,d,r}^{AD})}{(1 + \bar{t}_{i,d,r}^{AD})} \right)^{1-\sigma_D}}_{DOMESTIC} + \underbrace{(1 - \theta_{g,i,d,r}^{Dss}) \left( \frac{P_{g,i,r}^{Mss} (1 + t_{i,d,r}^{AI})}{(1 + \bar{t}_{i,d,r}^{AI})} \right)^{1-\sigma_D}}_{IMPORTED} \right\}^{\frac{1}{1-\sigma_{DM}}}$$

$$5. A_{i,d,r} = a_{i,d,r}^{ref} \left( \frac{P_{i,d,r}^{Aref}}{P_{i,d,r}^A} \right)^{\varepsilon_d}, \text{ where } P_{i,d,r}^A = \left[ \sum_g \left( \theta_{g,i,d,r}^D P_{g,i,d,r}^A \right)^{1+\sigma} \right]^{\frac{1}{1+\sigma}}$$

**Table 2. Value and Quantity Share of HS6 Tariff Lines in Specialty Cheese TRQIDs**

HS6 Line	TRQID11		TRQID12		TRQID13		TRQID14		TRQID15		TRQID16		TRQID17		TRQID18		TRQID19	
	Cheese Substitutes		Blue Veined Cheese		Cheddar Cheese		American Cheese		Edam/Gouda Cheese		Italian Cheese		Swiss-Type Cheese		Other Cheese Substitutes		Swiss-Type Cheese with Eye Formation	
	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V
<b>040610</b>	0.28	0.37	0.04	0.03	0.40	0.47	0.14	0.17	----	----	0.43	0.32	0.27	0.39	0.48	0.66	----	----
<b>040620</b>	3.34	3.99	----	----	----	----	6.64	10.27	----	----	3.67	3.12	----	----	0.36	0.44	----	----
<b>040630</b>	5.48	3.68	1.43	0.46	1.27	1.95	1.08	1.76	0.75	0.74	0.06	0.08	92.34	89.05	0.52	0.58	----	----
<b>040640</b>	----	----	98.53	99.51	----	----	----	----	----	----	----	----	----	----	----	----	----	----
<b>040690</b>	90.91	91.97	----	----	98.33	97.58	92.13	87.79	99.25	99.26	95.84	96.48	7.38	10.56	98.64	98.32	100.00	100.00
<b>Total</b>	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

<sup>a</sup> Q denotes quantity shares (%) and V denotes value shares (%)

<sup>b</sup> Source: Authors calculations from USITC's Interactive Tariff and Trade Database

**Table 3. TRQ Allocations in US Specialty Cheese Market**

		-----TRQID-----									<i>Model</i>	<i>MFN Unit</i>
		<i>11</i>	<i>12</i>	<i>13</i>	<i>14</i>	<i>15</i>	<i>16</i>	<i>17</i>	<i>18</i>	<i>19</i>	<i>Aggregation</i>	<i>Values</i>
<b>ARG</b>	<b>Quota</b>	100				143	4,808				4,782	0.6
		24				48	5,633				5,578	
	<b>Fill</b>	0.24				0.33	1.17				1.16	
<b>AUS</b>	<b>Quota</b>	1,133		1,617	1,000						1,249	0.7
		3,153		2,470	1,136						2,585	
	<b>Fill</b>	2.78		1.53	1.14						2.07	
<b>CAN</b>	<b>Quota</b>	1,141		833						70	828	0.9
		1,222		1,083						206	1085	
	<b>Fill</b>	1.07		1.30						2.95	1.32	
<b>EU15</b>	<b>Quota</b>	20,756	2,529	430	271	5,348	3,499	3,675	4,000	6,117	10,000	1.0
		22,800	2,692	724	159	6,326	4,625	5,625	1,977	11,000	12,100	
	<b>Fill</b>	1.10	1.06	1.68	0.59	1.18	1.32	1.53	0.49	1.80	1.21	
<b>NZL</b>	<b>Quota</b>	11,322		3,950	2,000						4,040	0.8
		13,600		8,226	1,985						10,700	
	<b>Fill</b>	1.20		2.08	0.99						1.49	
<b>ROE</b>	<b>Quota</b>	1,579				167	1,323	1,850	175	5,487	4,783	0.9
		1,728				45	1,302	857	20	4,780	3,555	
	<b>Fill</b>	1.09				0.27	0.98	0.46	0.11	0.87	0.88	
<b>SAM</b>	<b>Quota</b>	250					511			42	471	0.4
		255					1,178			110	987	
	<b>Fill</b>	1.02					2.30			2.64	2.10	
<b>MFN Quota % of Bilateral Quota</b>		502	N/A	240	170	26	14	80	N/A	86		
		1.4	N/A	3.5	5.2	0.5	0.2	1.5	N/A	0.7		

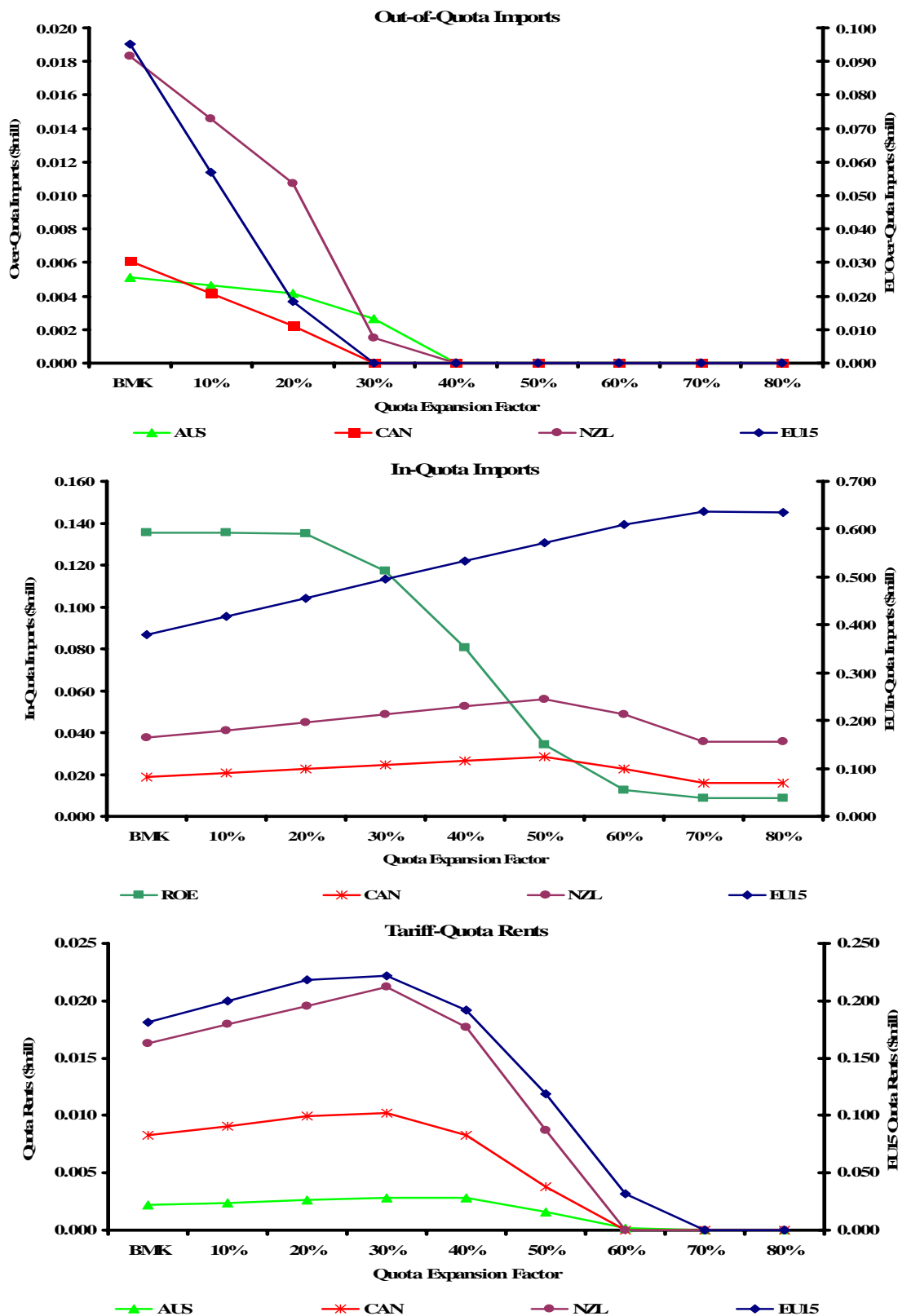
<sup>a</sup> Quota and Trade values are in metric tons (mt) and Fill equals Trade/Quota.

<sup>b</sup> Italian type cheeses include Romano, Reggiano, Parmesan, Provolone, Provoletti and Sbrinz

<sup>c</sup> ROE countries exporting specialty cheese to the US with bilateral quota allocations are Switzerland, Czech Republic, Hungary, Norway, Poland and Romania.

<sup>d</sup> EU15 TRQ information accounts for quota that was allocated separately to Sweden, Finland and Austria for TRQID11, TRQID15, TRQID17, TRQID18 and TRQID19.

<sup>e</sup> The amount of MFN quota allocated in the benchmark equilibrium is zero



**Figure 3. In and out-of-quota imports and quota rents from quota expansion**

Note: for scaling reasons, the EU15 imports are illustrated on the secondary vertical axis

**Table 4. Comparison of quota expansion, out-of-quota tariff cuts, simultaneous liberalization and MFN quota expansion**

-----Scenario-----							
(1)				(2)		(3)	
Quota Expansion				Out-of-quota Tariff Cut		Simultaneous Liberalization	
Liberalization	Composite Imports (%)	Composite Import Price (%)	Composite Import Price (%)	Composite Imports (%)	Composite Import Price (%)	Composite Imports (%)	Composite Import Price (%)
	Imports (%)	Import Price (%)	Import Price (%)	Imports (%)	Import Price (%)	Imports (%)	Import Price (%)
10%	0.85	-0.25	-3.53	13.51	-3.53	13.51	-3.53
20%	0.92	-0.27	-7.19	30.09	-7.19	30.09	-7.19
30%	6.38	-1.75	-10.98	50.55	-10.98	50.56	-10.98
40%	30.01	-7.19	-14.87	75.92	-14.87	76.30	-14.92
50%	96.20	-17.51	-18.84	107.60	-18.84	125.70	-20.78
60%	215.41	-28.16	-22.87	147.42	-22.87	219.52	-28.43
70%	270.31	-31.49	-26.94	197.89	-26.94	268.68	-31.40
80%	271.08	-31.54	-30.84	258.60	-30.84	272.61	-31.62
90%	271.85	-31.58	-31.62	272.61	-31.62	272.61	-31.62
100%	272.61	-31.62	-31.62	272.61	-31.62	272.61	-31.62

<sup>a</sup> All values are percent changes from benchmark equilibrium.

<sup>b</sup> The liberalization column is a percentage of full liberalization (i.e. all countries are in regime 1) and not the quota expansion factor. In figure 3, the bilateral quota expansions represented absolute 10 percent expansions and we saw that after a 70 percent expansion, EU15, CAN, NZL and AUS entered regime 1.

However, other countries like SAM required more than a 100 percent bilateral quota expansion to achieve full liberalization (regime 1). Thus, the numbers in scenario 1 (quota expansion) have been scaled to reflect 100 percent liberalization (versus a 100 percent quota expansion). All other values in scenarios 2-4 are actual expansions of 10 percent.



**Appendix 1. Country and Sector Information**

<b>Commodity Aggregation (19)</b>		<b>Country Aggregation (14)</b>	
(PDR)	Paddy Rice	ARG	Argentina
(WHT)	Wheat	AUS	Australia
(GRO)	Other Cereals	CAN	Canada
(V_F)	Vegetables and Fruit	EU15	European Union
(OSD)	Oilseeds	JPN	Japan
(C_B)	Sugar Cane and Beet	LAM	Latin America and Caribbean
(PFB)	Plant Based Fibers	MEX	Mexico
(OCR)	Other Crops	MNA	Middle East and North Africa
(CTL)	Bovine Cattle	NZL	New Zealand
(OAP)	Other Animal Products	ROA	Rest of Asia
(RMK)	Raw Milk	ROE	Rest of Europe
(WOL)	Wool	SAM	South America
(VOL)	Vegetable Oils and Fats	SAO	South Asia and Oceania
(MIL)	Dairy	USA	United States
(PCR)	Processed Rice		
(SGR)	Sugar		
(OFD)	Other Food Products		
(B_T)	Beverages and Tobacco		
(OTH)	All Other Goods		

## Appendix II. Calibration of the Sub-Sector Model

Benchmark production and demand at the sub-sector level were estimated using a constrained optimization approach, minimizing the squared distance between import demand and a share-weighted sum of sub-sector aggregate demand subject to (i) the sum of calibrated import demand ( $VAI^*$ ) equals aggregate import expenditure ( $VIM$ ); (ii) the sum over sub-sector goods ( $g$ ) of calibrated domestic demand ( $VAD^*$ ) equals value of sectoral supply; and (3) the sum of sub-sector import demand and domestic demand equals aggregate sectoral demand ( $VA$ ). Formally:

$$\min_{VAI^*, VAD^*} \Omega = \sum_{g,i,d,r} \left[ (1 + \bar{t}_{i,d,r}^{AM}) VAI_{g,i,d,r}^* - \lambda_{g,i,d,r}^M \left( (1 + t_{i,d,r}^{AM}) VAI_{g,i,d,r}^* + (1 + \bar{t}_{i,d,r}^{AD}) VAD_{g,i,d,r}^* \right) \right]^2$$

subject to,

$$(i) \quad \sum_d VAI_{g,i,d,r}^* = VIM_{g,i,r}$$

$$(ii) \quad \sum_g VAD_{g,i,d,r}^* = VDM_{i,r}$$

$$(iii) \quad \sum_d \left( (1 + \bar{t}_{i,d,r}^{AM}) VAI_{g,i,d,r}^* + (1 + \bar{t}_{i,d,r}^{AD}) VAD_{g,i,d,r}^* \right) = VA_{i,d,r}$$

where,  $\lambda^M$  is an import intensity target equal to import demand ( $VAI$ ) divided by aggregate expenditure (imports ( $VAI$ ) + domestic ( $VAD$ ) =  $VA$ ) at the sectoral (GTAP) level;  $VDM$  denotes sectoral domestic sales of dairy; and  $VA$  denotes aggregate sectoral demand. Once demand has been obtained, production is calculated by summing domestic demand and exports of sub-sector good ( $g$ ) in region ( $r$ ).