IMPACTS OF THE TRANS-PACIFIC PARTNERSHIP FOR US AND INTERNATIONAL DAIRY TRADE

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Abstract:

The Trans-Pacific Partnership (TPP) is widely anticipated to provide significant new market opportunities for US agricultural trade, including dairy products. In 2014, the US exported $3.6 billion worth of dairy products to TPP countries, which represents over half of total US dairy exports globally. While the agreement opens new markets for US dairy exports, the US also provided additional market access through country-specific tariff-quota allocations and the reduction or elimination of tariff-only dairy product lines, some of which will compete directly with domestic production. Therefore, whether the US dairy industry will gain overall from TPP remains an open research question. In this paper, we develop a global, source differentiated, partial equilibrium diary model to assess the likely impacts of the TPP on US and international dairy markets, inclusive of tariff-rate quota liberalization and projected to the year 2028. We consider two relevant policy simulations: (i) US ratification the TPP agreement; and (ii) one where the US fails to ratify the TPP. In both scenarios, we also consider changes in a few key underlying assumptions – namely when the tariff-quota is binding and one where we allow Australia and New Zealand supply elasticities to be more elastic to evaluate the effect of more intense competition on US domestic production.

Keywords: *Dairy Product trade, TPP, Tariff-Rate Quotas (TRQ), Country-Specific Quotas (CSQ), Trade Liberalization, Partial equilibrium, source-differentiation*
JEL Classification: *F1, Q10*

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1. Background

The Trans-Pacific Partnership (TPP), for which negotiations concluded on October 5, 2015 and draft text was made available on November 15, 2015, is widely anticipated to provide significant new market opportunities for US agricultural exports. The agreement provides for substantial market access by reducing or eliminating tariffs, or providing new access for a specific quantity of imports at a lower tariff where tariff elimination was not possible. The TPP also provides novel mechanisms to address non-tariff issues including rapid response frameworks for Sanitary and Phyto-Sanitary (SPS) measures and new provisions for geographic indications (GIs).

For dairy trade, US exports stand to gain significant new market access in Japan and faster growing Pacific Rim countries, and more moderate access in Canada which opened up roughly 3.25 percent of its overall dairy market for TPP countries. While small, the fact that TPP made some headway into the Canadian market is significant as Canada excluded dairy (and poultry and eggs) from the North American Free Trade Agreement (NAFTA).

The US also provided new market access to its dairy market. While most of this new access is provided through country-specific quota (CSQ) allocations and the elimination of in-quota duties, the US will eliminate tariffs for certain products over a period of time.[1] Moreover, quota amounts have growth provisions that are reciprocal (in the case of the US and Canada) or are similar to other FTAs (CSQs for New Zealand are similar to those established for Australia in the US-Australia FTA).

Given these new market openings, how will the TPP impact U.S. exports and imports of dairy products? How these market forces will interact is an open empirical question and depends

[1] For details, see http://www.fas.usda.gov/sites/default/files/2016-05/tpp_ag_overview_-_long_05-09-16.pdf

critically on the type of liberalization offered through tariff-rate quotas (TRQs) and on the existing TRQ regime in which exporters are operating.

In this paper, we develop a global, source differentiated, partial equilibrium diary model to assess impacts of changes in dairy trade policies agreed to in the TPP agreement. These provisions call for an immediate reduction or elimination of most tariff and in-quota tariff rates and a 10 year phase-in period (with a few exceptions) for increases in tariff rate quota (TRQ) levels. We consider four relevant policy scenarios: (i) a forecast of income and population growth in the TPP and other model regions; (ii) a scenario where the US ratifies the TPP agreement; (iii) a scenario where the US fails to ratify the TPP; and (iv) a TPP scenario with an enhanced supply response from Australia and New Zealand. The model includes five processed dairy products: fluid milk and cream, butter and spreads, cheeses, whey, and milk powders (skim and whole milk powders). We include 13 countries and regions that are major dairy producing regions, are larger importers or exporters of dairy products, or are potentially key members of the TPP agreement. For example, while Malaysia and Vietnam are not large dairy markets initially, they are faster growing markets recently and with significant projected income and population growth, could become important importers. The US and other TPP members will gain preferential access to these markets under the TPP provisions.

2. Model Setup

For the purposes of illustrating the market price, quantity and welfare effects of the proposed TPP agreement for US and international dairy trade, we develop a static, global, partial equilibrium, source-differentiated, model of world dairy trade with five processed dairy products - butter and spreads, cheese, whey, powders (skim and whole milk powder), and fluid milk and cream – and eleven individual regions (Australia (AUS), Canada (CAN), European Union

(EUR), Indonesia (IDN), Japan (JPN), Korea (KOR), Mexico (MEX), Malaysia (MYS), New Zealand (NZL), United States (USA), and Vietnam (VNM) and two aggregate regions consisting of the Rest of Americas which includes TPP members Chile and Peru (XSM) and a Rest of the World composite region (XWD). The two individual non-TPP members, Indonesia and Korea, are included because Indonesia also has significant projected income and population growth and Korea has at various stages of the negotiations indicated its interest in joining the TPP. Because of the existence of product differentiation through the use of producer brands and/or regional identifiers, we assume that all dairy products are differentiated by their country of origin. Thus, the price of a given dairy product can vary across destinations for a given producing region.

Due to the assumption of differentiated products, we use a nested Constant Elasticity of Substitution (CES) utility structure to represent preferences for a single, representative consumer in each region. As shown in Figure 1, we specify a three level nested CES utility function. The top-level of this structure depicts the potential substitution between dairy and all other products. We include a composite "all else" product in order to have a complete demand system and therefore be able to derive an expenditure function, which will be used to compute the equivalent variation welfare measures for the alternative policy scenarios.

The second-level of the preference structure represents the potential substitution between different dairy products. For example, the representative consumer can substitute between cheese and butter as their relative prices change. Finally, the bottom-level represent the potential substitution between different sources of a given dairy product. For example, the representative consumer can substitute between domestically produced cheese or imported cheese for a given producer as their relative prices change. The numbers given within each nest is the assumed starting values of the elasticities of substitution. We assume limited substitution between dairy and all other goods (0.3) as well as between dairy products (0.5). However, there is greater scope to substitute between sources in the bottom-level nest where we use the Armington elasticity value for dairy products from the GTAP database (3.65). The uncompensated demand functions for this preference structure are given in equation (A.1) in the Appendix. In addition, equations (A.7) and (A.8) specify the CES price indices used in the model.

Similarly, we use a nested Constant Elasticity of Transformation (CET) revenue function to represent technology for a single multi-product representative dairy industry in each region. This allows us to abstract from a more complex dairy production structure that involves differing degrees of joint products that can be produced from raw milk. Figure 2 illustrates the structure of the nested CET function. At the bottom-level in Figure 2, firms in the dairy industry can substitute between different processed dairy products as their relative prices change. At the top-level, firms can also substitute between selling a particular dairy product to different destinations as relative prices change under the different policy experiments. For example, an increase in the price of cheese in the domestic market will cause firms to substitute cheese production away from export markets to the domestic market. The numbers given in each nest in Figure 2 are the assumed values of the elasticities of transformation. Because of the joint production of some products (cheese and butter), we assume there is limited ability for supply firms to substitute between dairy products for a given production level of raw milk and therefore use an inelastic elasticity of transformation of -0.5 in the lower nest. Conversely, because firms may be able to shift between home and foreign markets (in the absence of policy barriers) more easily, we assume an elasticity of transformation of -5.0 at the top level. Equations (A.5), (A.9), and (A.10) specify the conditional supply functions and the CET price indices used in the model.

The location of the CET production possibilities frontier in each region is determined by the level of an aggregate dairy factor. This aggregate factor can be thought of as being comprised of raw milk, labor, capital, and other inputs used in the processing of dairy products. As such, we assume that raw milk is the limiting input with the most inelastic supply response in the short run, due to the biological lags in raw milk production. Thus, we assume that the supply response of this aggregate factor is equal to the supply response of raw milk. We use the raw milk supply elasticity estimated by Bozic, et al. (2012). Their estimated supply response is very inelastic in the short-run, approximately 0.1 for the first year, and increasing by approximately 0.1 in subsequent years. We assume the same raw milk supply response in all other regions, due to a lack of similar estimated supply elasticities internationally.

A linear function is used to represent the supply of the aggregate dairy factor in each region. The quantity of the aggregate factor (V_o) is a function of the aggregate price of processed dairy products, which is represented by the CET price index for all dairy products. As the price of processed dairy products increase, the dairy processing sector will want to expand production and thus must attract more of the aggregate dairy factor in order for the CET production possibilities frontier to shift outwards. The parameter δ_o in equation (A.11) is chosen to match the estimated supply elasticity from Bozic, et al. (2012).

We explicitly model TRQs following van der Mensbrugghe, et al. (2003), Harrison, et al. (2004), and Grant, Hertel and Rutherford (2007). Figure 3 depicts the three alternative outcomes for a TRQ, depending on the level of import demand. TRQs combine elements of quantitative restrictions (*Quota*) and tariffs (t^{in}, t^{out}). With low import demand (*ED*) (regime 1), import demand is less than the quota level and 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}). The price in the importing country is equal to the exporter price (P^w) multiplies by one plus the in-quota ad valorem tariff (t^{in}). While tariff revenues are collected on in-quota imports (area *B*), the quota is not binding and quota rents or price premiums do not accrue. In regime 2, import demand is stronger but the out-of-quota tariff (t^{out}) is potentially prohibitive. This is analogous to a pure quota situation where domestic prices are determined by the intersection of excess demand and the vertical portion of the excess supply function, and may range between the exporter's price plus the in-quota tariff and the exporter's price plus the over-quota tariff (t^{out}). The difference between the import price and the in-quota tariff rate represents the "price premium" which can be a difficult calibration step in the model because it requires specific knowledge as to which TRQ lines are binding and the level of the price premium. The analysis is further complicated by the administration methods of the quota itself, which can take many different forms but is somewhat simplified in the TPP agreement because the TRQs guarantee some access for TPP countries or were negotiated as country-specific quotas. Note that 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 C). Again, tariff revenues are collected on all in-quota imports (area B).

Finally, when import demand is sufficiently strong as in regime 3, the out-of-quota tariff (t^{out}) applies. Here, in the case of country-specific quotas imports may exceed the quota level and the import price is equal to the exporter price plus the over-quota tariff rate. However, in cases where the TRA is available to multiple countries, in-quota imports face a much lower tariff rate (t^{in}) and the problem arises as to which suppliers are granted the right to supply under the quota since exporters are willing to supply Q^1, 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 in-quota and the out-of-quota tariff price times the quota level (area A).

To represent these three alternative TRQ outcomes, we use a set of complementarity conditions to represent country-specific TRQs. Because the level of import demand can be less than or exceed the quota level, the total import quantity is decomposed into two components in equation (A.2): the in-quota quantity plus the over-quota quantity. Equation (A.3) constrains the in-quota quantity to be less than or equal to the quota level. The complementarity variable for this equation is the level of the price premium. If the quota is not binding (regime 1), then the price premium is zero. If the quota is binding, then the price premium will be positive and can range between zero and the difference between the in-quota and over-quota tariff rates. Equation (A.5) enforces this range on price premium by stating that the over-quota tariff must equal or exceed the in-quota tariff rate plus the price premium. If the over-quota tariff exceeds this sum (regime 2), then the level of over-quota imports is equal to zero. If the over-quota tariff rate equals this sum, then the level of over-quota imports is greater than or equal to zero (regime 3).

Four policy scenarios are conducted to forecast the likely impacts of the TPP on US and international dairy markets through 2028, with the maintained assumption that the TPP will enter into force in 2018. These are summarized as follows:

1. Forecast Scenario – projects GDP growth in all markets to 2028
2. Forecast + TPP implementation over 10 years
3. Forecast + TPP implementation absent the US
4. Forecast + TPP implementation + enhanced Australia/New Zealand supply response

The forecast scenario is designed to capture important emerging market per capita income growth in the Asia-Pacific regions in the model that will likely drive a portion of international dairy trade patterns going forward independent of TPP policy changes. For some markets such as Japan, however, income and population growth is predicted to remain flat according to the latest projections from the Economic Research Service.[2]

3. Data

Bilateral trade values and quantities were taken from the United Nations Conference on Trade and Development (UNCTAD) Commodity Trade Statistics (COMTRADE) database and averaged over the period 2012-2014 to reflect the model's baseline trade situation. The Foreign Agricultural Service (FAS)'s Global Agricultural Trade System (GATS) was used to cross check the UN data for US exports and imports. Unit value prices were imputed from the bilateral trade data by dividing the value of trade by the quantity of trade. For some whey product lines, we disaggregated the HS6-digit tariff lines to the 8-digit level to remove liquid forms of whey traded predominantly between the US and Canada to reflect the underlying whey production data which was collected as solid or dried forms. Similarly, for other sectors such as cheese, HS8-digit trade data were used to compute TRQ fill ratios and then aggregated to the model's sector level using the quota level as weights. In and out of quota tariff rates and quota fill ratios were obtained from the FAS for the US and its FTA partners, and the Market Access Maps (MACMAPS) dataset for most other countries along with national statistical agency sources such as for the EU, Canada and Japan. All policy variables reflect applied in and out of quota tariff rates averaged over the period 2012-2014 and reflect country-specific and FTA preferential tariff rates and quota allocations.

Table 1 reflects the initial policy setting for in- and out-of-quota tariff rates, the quota-weighted average fill rates for each sector and the country-specific quota allocations used in the

[2] See http://www.ers.usda.gov/data-products/international-macroeconomic-data-set.aspx for exact figures.

model's baseline for selected TPP countries. The figures indicate a high fill ratio for Canada's TRQs , compared to lower fill rates for many US TRQs, with the exception of some cheese TRQ lines from the EU. Most of Canada's tariff-quota is allocated on an any-country or global quota basis with country-specific reserves for New Zealand in butter and powder and the EU for some cheese lines. Australia and New Zealand also stand out as relatively unprotected dairy markets with many tariff lines entering duty free. Japan maintains a large government controlled TRQ policy for many dairy products including butter products, whey and powder (Obara, Dyck and Stout 2005). Like Canada, Japan limits TRQ imports with moderate in-quota tariff levels and very high out of quota tariff rates up to 571 percent for some whey products. The model includes many other preferential TRQ policies for the EU, Korea, Peru and Chile in the XSM aggregate, and Mexico.

Baseline production and domestic producer price data were retrieved from the Food and Agricultural Organization for all sectors in the model: fluid milk and cream, skim and whole milk powder, whey, cheese and butter. Domestic consumption data, which are more challenging to find, were computed as a residual in the model once exports were subtracted from domestic production. Finally, per capita income projections to 2028 were taken from the ERS's Macroeconomic datasets.

4. Results

We begin by discussing the results of the forecast simulation through 2028. Here, income and population growth are the strongest in the Southeast Asian countries, Mexico, and the rest of the world. These regions also have the largest income elasticities for dairy products. Dairy exports from Australia and New Zealand, two of the main competitors for the US dairy industry, are initially more oriented to these fast growing regions than to the US market. The higher demand growth in these regions causes both Australia and New Zealand to further shift their exports to these emerging markets and away from US and Canadian markets. Thus, in the forecast simulation scenario, we see a slight drop in the fill-rates for US dairy TRQs.

In scenario two, which represents full implementation of the TPP for dairy product trade, we find that for US imports the elimination of relatively low in-quota tariffs does not provide a large reduction in the price of imported dairy products relative to domestic dairy products for US consumers. Initially, US in-quota tariff rates are generally less than 10% (12.5% on some cheese being the highest). In addition, some of the effect of the tariff reduction is offset by price increases in dairy products from Australia and New Zealand, due to increased demand from tariff reductions in other TPP regions. When combined with the reduction in US fill-rates in the forecast simulation, a significant amount of the increased quota under the TPP does not get utilized, with the exception of cheese from Canada. Overall US dairy imports increase 14,000 metric tons (MT)[3] or by over $50 million by the ninth year of TPP implementation, the majority of which is cheese imports. New Zealand and Canada are the largest beneficiaries of the increase in US cheese imports at $6 and $2.5 million, respectively.

The gains in US exports of dairy products is much larger. Overall, US exports increase by approximately 35,000 MT in year 3 to 50,000 MT in year 9 of the agreement. The majority of this increase is cheese exports reaching 30,000 metric tons of exports to TPP countries. For most products, Canada and Japan account for a large share of the increase in exports. Japan has relatively high initial in-quota tariff rates, which exceed 30% for some products. Elimination of those tariffs in the final year of TPP implementation results in substantial reductions in the price

[3] Trade quantities are summed across all commodities covered and are unadjusted.

of imported dairy products into the Japanese market. For Canada, the increase in imports is due to the expansion of TRQ quota levels.

If the US does not ratify the TPP agreement, US dairy exports decrease by approximately 5,500 MT, or nearly $25 million as US producers do not gain preferential access to countries within the TPP. The largest losses occur on US exports of cheese products to Mexico and butter and spreads to Vietnam. Overall, the US suffers a welfare loss from non-participation in the TPP as remaining TPP countries reorient their import patterns toward member partners.

5. Conclusions

Agricultural market access inevitably surfaces as a contentious issue in bilateral, regional and multilateral negotiations. For international dairy trade, the TPP was no different. Summarizing the results of the TPP dairy analysis is difficult because each member country has a different stake in the trade negotiations depending on its initial tariff and quota levels and trade position in world dairy markets. However, a few preliminary results are worth summarizing.

First, our forecast scenario through 2028 for GDP and population projections indicates that international dairy trade is likely to experience a re-orientation towards faster growing markets in the Pacific Rim. Income growth is strongest in Vietnam, Indonesia, Malaysia, Mexico, and rest of world aggregate. These regions also tend to have larger population growth and income elasticities for dairy consumption. This has important implications for US TRQ fill rates and the extent to which Australia, New Zealand, the US and to some extent Canada shift the pattern of their dairy export supplies.

Second, the extent to which TRQ liberalization generates additional market access gains depends on the regime exporters are operating in the baseline. Because many US dairy TRQs have lower fill rates, with the exception of a few product lines from the EU, New Zealand and potentially Australia, eliminating in-quota tariff rates would likely have a greater effect on trade than an increase of the quota amount. However, even with the elimination of in-quota duties under TPP, the model results suggest that US TRQs are still not likely to fill. . The only exception to this is the scenario where we consider more extreme (i.e., elastic) supply responses from Australia and New Zealand where imports are four times larger overall compared to our base TPP scenario. Thus, overall the increase in US dairy imports is expected to be less than the gains it achieves on exports.

Third, in Canada, and to some extent Japan, the baseline numbers suggest most TRQs are filled or nearly filled. Thus, because the quota is binding, simultaneous elimination of in-quota tariffs and expansions of the quota level itself, is an optimal outcome and will likely generate significant export opportunities for the US and other TPP countries. For example, in these two markets alone, our numbers suggest US dairy exports will increase $113 and $100 million, respectively, by year nine of TPP implementation which is nearly ten percent of all US dairy exports currently.

Finally, our preliminary findings suggest that the overall welfare implications from TPP implementation is expected to be positive on net for US dairy markets as any losses experienced by consumers from higher world prices and increased import demand by faster growing nations is offset by gains in producer surplus and revenues, particularly for raw milk producers and downstream processed cheese, and to some extent butter, suppliers.

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Table 1. Initial TRQ Policy Setting, Selected Markets

	BUTTER			WHEY			CHEESE			POWDERS		
Import Market	iqt	oqt	Fill	iqt	oqt	Fill	iqt	oqt	Fill	iqt	oqt	fill
USA	0.06[a]	0.51	AUS: 0.56 KOR: 0.24 XSM: 0.13 Any: 0.82	0.09[e]	0.25[e]	AUS: 0.10 XSM:0.24 Any: 0.09	0.12	0.18	AUS: 0.44 NZL: 0.60 CAN: 0.98 EU: 1.0 XWD: 0.64 Any: 0.2	0.01[a]	0.34	AUS: 0.76 CAN: 0.76 EU: 0.85 XSM: 0.52
CAN	0.07[b]	2.45	NZL: 0.95 Any: 1.00	0.03[b]	2.08	Any: 1.00	0.01[b]	2.45	EU: 1.00 Any: 1.00	0.03[b]	3.15	NZL: 1.00 Any: 1.00
NZL	0.00	---	---	0.05[d]	---	---	0.00	---	---	0.05[d]	---	---
AUS	0.01[c]	---	---	0.00	---	---	0.02[c]	---	---	0.00	---	---
JPN	0.35	1.39	NZL: 0.95 Any: 1.00	0.30	5.71	0.77	0.32	---	---	0.20	1.50	Any: 0.66
Other notables	<u>Many other preferential TRQs & tariffs coded:</u> • EU (PWD, CHS, WHY, FMK, BUT), preferences and/or CSQs for KOR, NZL, XSM (PER), XWD (EFTA) • KOR (BUT, WHY, CHS, PWD) with CSQs for USA, AUS, NZL, EU • XSM – some reserved CSQs for US in FTA markets • Mexico - 2011 opened 80K (mt) global PWD TRQ											

Notes: iqt and oqt denote the in- and out-of-quota tariff rates, respectively, on an ad valorem equivalent basis; Fill denotes the quota fill rate; BUT, CHS, PWD, WHY and FMK denote butter and spreads, cheeses, milk powders, dried whey, and fluid milk and cream, respectively.

[a] Duty free for AUS, CAN, MEX, KOR and select XSM countries

[b] Duty free for US

[c] Duty free for IDN, KOR, MEX (excl chs), MYS, NZL, USA, VNM, XSM

[d] Duty free for AUS, CAN, IDN, MYS, VNM and some XSM, XWD countries

[e] In-Quota: duty free for MEX and XSM, 1% for AUS, CAN, 5% for KOR; <u>Out-of-Quota</u>: duty-free for MEX, 14% for AUS, CAN, KOR, XSM

Figure 1. Structure of Nested Constant Elasticity of Substitution Utility Function

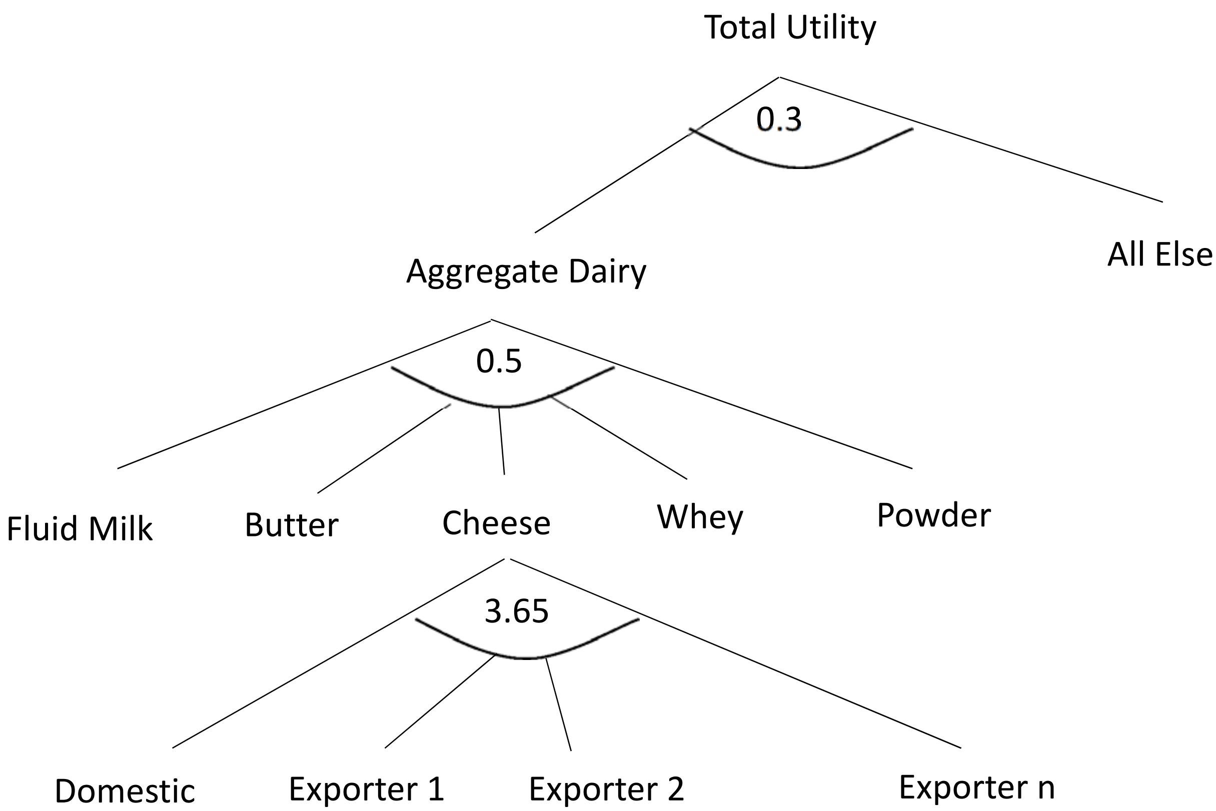


Figure 2. Structure of Nested Constant Elasticity of Transformation Revenue Function

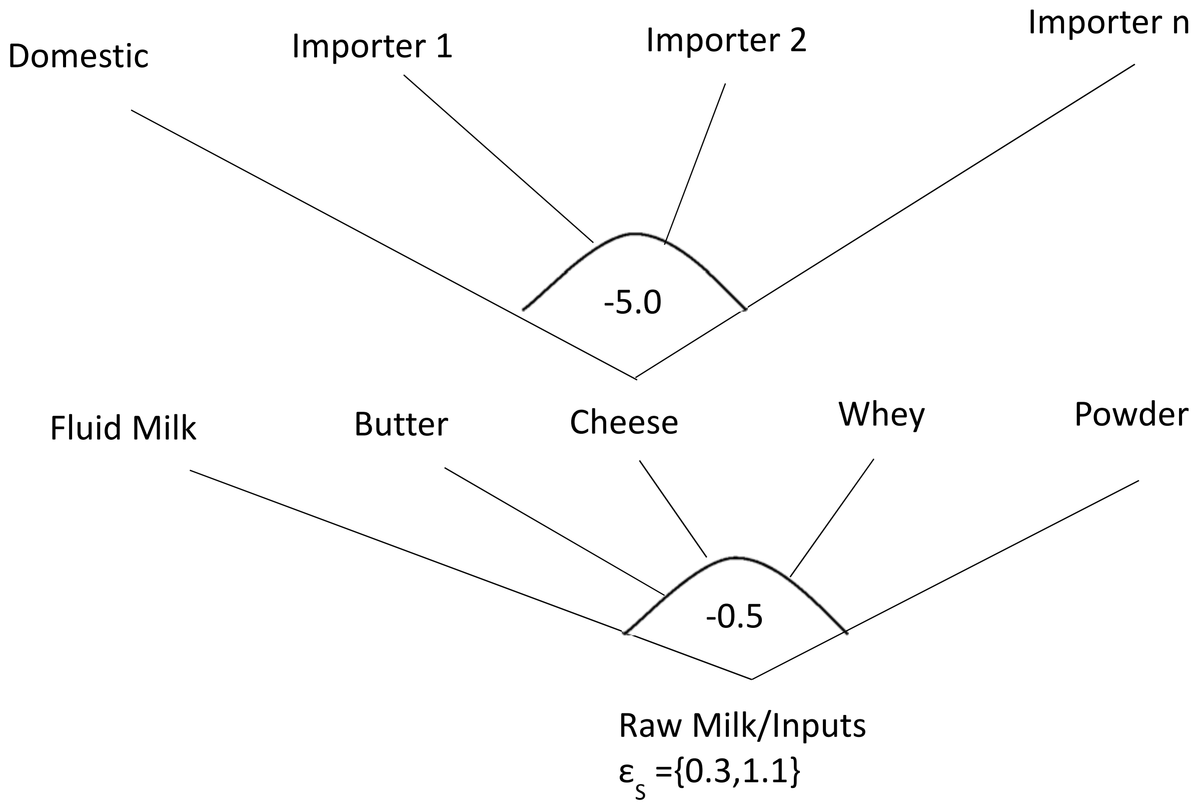
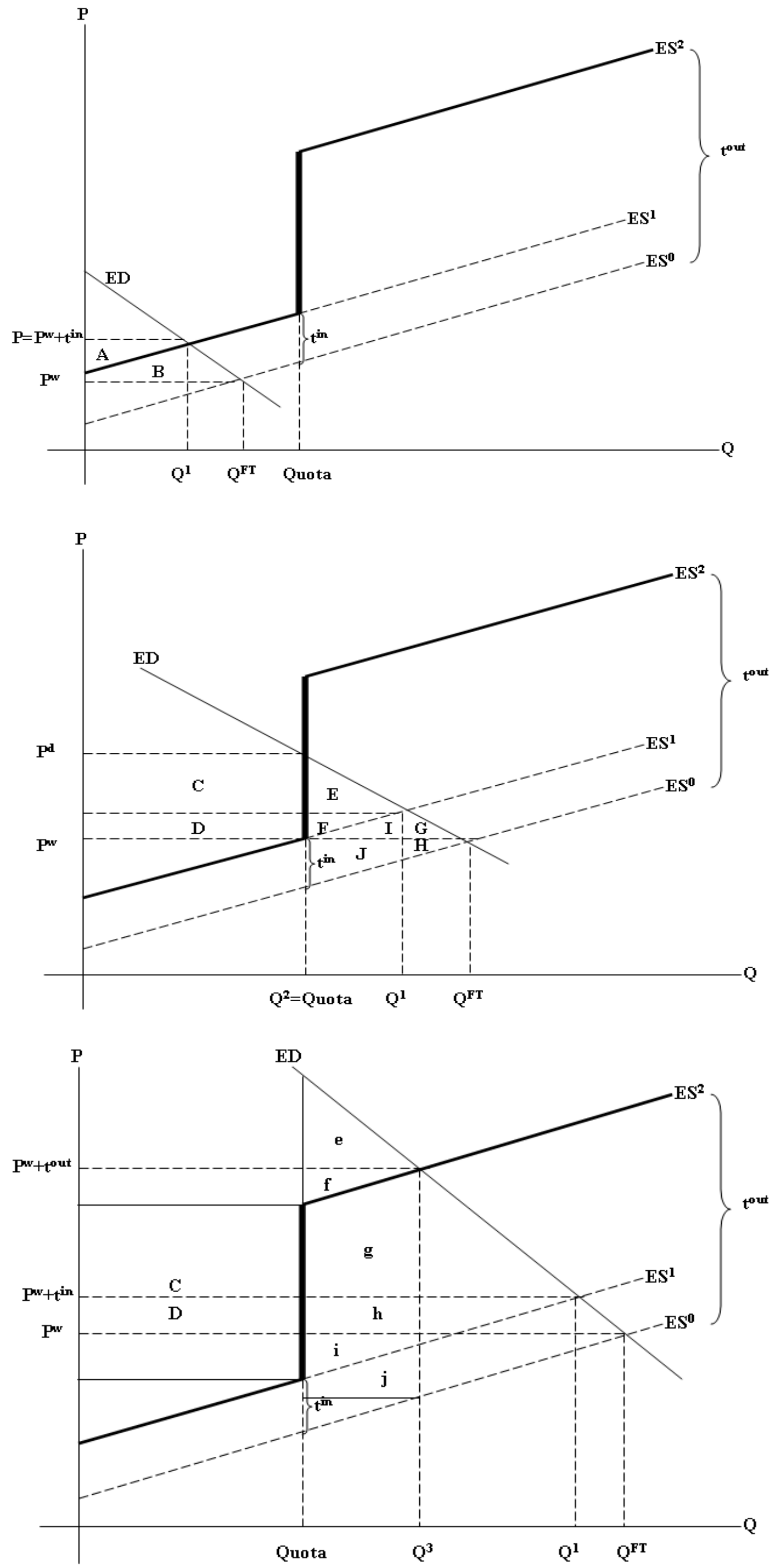


Figure 3. Economics of Tariff-Rate Quotas



Regime 1 – Tariff Only

Regime 2 – Pure Quota

Regime 3 - Mixed

Appendix A: Model Equations and Variable Definitions

Consumer Demand Equations

(.1)
$$x_{iod} = \Big[\Big[a_d b_{id} c_{iod}\left[p_{iod}\left(1+itariff_{iod}+prem_{iod}\right)\right]^{-\sigma_{3d}} pd2_{id}^{[\sigma_{3d}-\sigma_{2d}]} pd1_{id}^{[\sigma_{2d}-\sigma_{1d}]}$$
$$I_d\left[\left(IG_d-1\right)\eta_d+1\right]\Big]\Big/\left[a_d PP_d^{1-\sigma_{1d}}+\left(1-a_d\right)\right]\Big] pop_d\, pgrow_d$$

Linkage for In-Quota and Over-Quota Demand

(.2)
$$x_{iod} = xi_{iod} + xo_{iod}$$

Quota Levels

(.3)
$$quota_{iod} \geq xi_{iod};\ prem_{iod}\left(quota_{iod} - xi_{iod}\right) = 0$$

Linkage for In-Quota and Over-Quota Tariff Rates

(.4)
$$otariff_{iod} \geq itariff_{iod} + prem_{iod};\ xo_{iod}\left(otariff_{iod} - itariff_{iod} - prem_{iod}\right) = 0$$

Processed Dairy Product Supply Equations

(.5)
$$y_{iod} = \beta_{io}\lambda_{iod}\, p_{iod}^{-\sigma_{T2io}}\, ps2_{io}^{[\sigma_{T2io}-\sigma_{T1o}]}\, ps1_o^{\sigma_{T1o}} V_o$$

Market Clearing Conditions

(.6)
$$y_{iod} = x_{iod}$$

Price Index for Processed Dairy Products – Consumption

(.7)
$$pd2_{id} = \left[\sum_o c_{ior}\, p_{iod}\left(1+itariff_{iod}+prem_{iod}\right)^{1-\sigma_{3d}}\right]^{\frac{1}{(1-\sigma_{3d})}}$$

Price Index for Dairy Aggregate – Consumption

(.8)
$$pd1_d = \left[\sum_i b_{id}\, pd2_{id}^{(1-\sigma_{2d})}\right]^{\frac{1}{(1-\sigma_{2d})}}$$

Price Index for Processed Dairy Products – Supply

(.9) $$ps2_{io} = \left[\sum_{d} \lambda_{iod} p_{iod}^{(1-\sigma_{T2io})} \right]^{\frac{1}{(1-\sigma_{T2io})}}$$

Price Index for Aggregate Dairy – Supply

(.10) $$ps1_{o} = \left[\sum_{i} \beta_{io} ps2_{io}^{(1-\sigma_{T1o})} \right]^{\frac{1}{(1-\sigma_{T1o})}}$$

Supply of Aggregate Dairy Factor

(.11) $$V_o = \alpha_o + \delta_o ps1_o$$

Indices:

i = processed dairy product (butter, cheese, whey, powder, and fluid milk).
o = origin region
d = destination region

Table A1. Variable and Parameter Definitions

Variable/Parameter	Definition
Endogenous Variables	
x_{iod}	Quantity of product *i* from region *o* consumed in region *d*
p_{iod}	Price of product *i* from region *o* in region *d*
$pd2_{id}$	Demand price index for composite product *i* in region *d*
$pd1_d$	Demand price for composite dairy in region *d*
xi_{iod}	Quantity of in-quota product *i* from region *o* consumed in region *d*
xo_{iod}	Quantity of over-quota product *i* from region *o* consumed in region *d*
$prem_{iod}$	Premium on in-quota tariff rate for product *i* from region *o* in *d*
y_{iod}	Supply of product *i* from region *o* to region *d*
$ps2_{io}$	Supply price index for composite product *i* in region *o*
$ps1_o$	Supply price index for composite dairy in region *o*
V_o	Supply of aggregate dairy factor of production in region *o*
Exogenous Variables	
$itariff_{iod}$	In-quota tariff rate on product *i* from region *o* in region *d*
$otariff_{iod}$	Over-quota tariff rate on product *i* from region *o* in region *d*
$quota_{iod}$	Quota on product *i* from region *o* in region *d*
I_d	Per-capita income (GDP) in region *d*
IG_d	Growth in per-capita income in region *d*
pop_d	Population in region *d* (millions)
$pgrow_d$	Population growth in region *d*
Parameters	
a_d	Shift parameter in top nest of CES utility function in region *d*
b_{id}	Shift parameter in second nest of CES utility function in region *d*
c_{iod}	Shift parameter in bottom nest of CES utility function in region *d*
σ_{1d}	Elasticity of substitution between dairy and all else in CES utility function
σ_{2d}	Elasticity of substitution between composite dairy products in CES utility function
σ_{3d}	Elasticity of substitution between sources of dairy product in CES utility function
η_d	Income elasticity for aggregate dairy in region *d*
β_{io}	Shift parameter for composite dairy products in CET revenue function
λ_{io}	Shift parameter for dairy products by destination in CET revenue function
σ_{T1o}	Elasticity of transformation between composite dairy products in CET revenue function
σ_{T2io}	Elasticity of transformation between dairy product destinations in CET revenue function
α_o	Intercept for supply function for aggregate dairy factor of production
δ	Slope of supply function for aggregate dairy factor of production