

# Impacts of Trade Liberalization in Canada's Supply Managed Dairy Industry

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Trade is an integral part of the Canadian economy. The main institutional drivers governing trade are bilateral and multilateral agreements outlining permissible trade distorting measures. Since its inception in 1972, Canada's supply management system has remained protected throughout trade negotiations. The system appears, by any economic measure, to be having an increasingly disproportional influence in recent trade negotiations. However, trade agreements serve not only to maximize social surplus, but also to maximize some measure of political welfare. Canada has recently negotiated three prominent trade agreements: the Canada-European Union Comprehensive Economic and Trade Agreement (CETA) came into effect in the latter part of 2017; the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP) came into effect at the end of 2018; and the Canada-United States-Mexico Agreement (CUSMA) could come into effect as early as late 2019. Collectively, these agreements have guaranteed increased market access for fresh and processed dairy products. We build a spatial partial equilibrium model of the Canadian dairy industry consisting of three regions and ten commodities to assess the individual and cumulative effect of these trade agreements. We pay particular attention to the institutional drivers within today's dairy sector: milk protein concentrates; component pricing including Class 7; and differential demand growth. We find that the aggregate impacts are: (i) a 7.0% decrease in the marginal retail price; (ii) a 4.7% decrease in the blended producer price; and (iii) an overall increase in social welfare of 5.5%. Worth noting, the decrease in producer surplus varies from 3.1% in the western region to 6.3% in the eastern region. Our results may be relevant to future negotiations as well as the publicly promised compensation package for dairy producers.

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# 1 Introduction

*"[T]he issue - which Canadians are very aware was a difficult one and where the U.S. wanted increased access - was access to the Canadian dairy market"* declared Minister of Foreign Affairs Chrystia Freeland in reference to the recent renegotiation of the North American Free Trade Agreement (NAFTA); (Chrystia Freeland as quoted in CBC News, 2018).

The protection of specific agricultural industries has been one of the more polarizing issues within the negotiations of the CETA, CPTPP, and CUSMA. With respect to Canada, its supply managed industries and in particular, its dairy sector, appear to have been quite contentious. Agriculture has always been a sensitive issue despite it often being dwarfed by the value of trade being negotiated (Gaisford and Kerr, 2001). For example, Canada's dairy sector contributes 0.9% to total GDP while aggregate exports and imports contribute 30.9% and 33.2% respectively (Dairy Farmers of Canada, 2018; Global Affairs Canada, 2018a). However, political as well as economic motives -- both perceived and real -- have always made trade agreements difficult to negotiate (Grossman and Helpman, 1994; Anderson and Raussler, 2013). The purpose of this manuscript is to estimate the economic effects to the Canadian dairy sector from CETA, CPTPP, and CUSMA individually and collectively while identifying the differential impacts across space, products, and levels of the supply chain.

The signing of CETA, CPTPP, and CUSMA has given Canada preferential access through trade agreements to nearly 1.5 billion consumers and 60% of global GDP (Global Affairs Canada, 2018b; World Bank, 2018). Each of these new trade agreements have eliminated many of the barriers to trade, and notably conceded new dairy market access to foreign countries. CETA was signed between Canada and the European Union (EU) in 2016 and brought into force on September 21, 2017. When fully implemented the agreement will eliminate 99% of the EU's tariff lines on Canadian products, up from 25% previously.<sup>1</sup> CETA opens up access for procurement of government projects, increases labour mobility, and establishes a chapter on regulatory conformity. The major dairy concession in CETA is increased market access for European cheese into Canada; 16,000 metric tonnes (mt) of all cheese, 1,700 mt of industrial cheese, and a reallocation of 800 mt of cheese tariff rate quota (TRQ) to the EU within Canada's WTO obligations.

The renegotiation of the Trans-Pacific Partnership (TPP) after the United States dropped out in 2017, was signed in March 2018 and brought into force on December 30, 2018. Once fully implemented, 99% of tariff lines will be removed between CPTPP countries. Canadian exports to CPTPP countries will experience a removal of 94% of agricultural tariff lines, 99% of industrial product tariff lines, and 100% of tariff lines on fish and forestry products. The renegotiation of CPTPP involved Canada successfully including enforceable

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<sup>1</sup>Each tariff line refers to tariffs on one product. The removal of a tariff line indicates that the good is traded duty-free.

chapters on both labour and the environment plus the removal of provisions on intellectual property. In regards to Canadian supply managed poultry, eggs, and dairy sectors, Canada maintained the same increased market access commitments agreed to within TPP. This amounts to 3.25% of dairy market access for CPTPP countries.

The renegotiation of NAFTA, originally signed in 1994, was completed in September 2018 with the new CUSMA agreement signed by all parties on November 30, 2018. CUSMA largely maintains much of the original NAFTA with updates to encompass the modern trade environment. Notable changes include increased North American content requirements in autos, a sunset clause, and a partial opening of the supply managed dairy sector.<sup>2</sup> Dairy concessions, of which there were none in the original NAFTA, have involved Canada conceding approximately 3.59% dairy market access, *superficially* eliminating the domestic policy of Class 7, and imposing export restrictions on skim milk powder (SMP) and infant formula. The CUSMA agreement indicates that Class 6 (in Ontario) and Class 7 (nationally) must be removed. More importantly, it states that the pricing formula of the product which falls under these classes -- non-fat solids within SMP -- must be no lower than the formula used by the U.S. Currently, pricing of class 7 is at the minimum of three different world prices and thus is bounded above by the U.S. price. *As a result, the removal of Class 7 within CUSMA is actually a price increase for Canadian producers with respect to the product in Class 7 (non-fat solids within SMP).*

To estimate the impacts of these trade agreements on Canada's supply managed dairy industry we built a spatial partial equilibrium model. Previous Canadian dairy models have looked at the dairy industry in a broad capacity. Duff (1996) developed an econometric model of the Canadian fluid milk industry that takes into account imperfect competition. Meilke, Sarker, and Le Roy (1998) assessed the potential impacts of increased trade flows between Canada and the US. Larivière and Meilke (1999) developed a dairy model that disaggregated industrial milk from one broad category into a series of products to evaluate impacts in a global context. Rude and An (2013) developed a model that included multiple industrial products to assess the impacts of the Trans Pacific Partnership on Canada. Carter and Mérel (2016) developed a model to assess the removal of supply management with short- and long-run impacts if producers were able to export competitively in global markets. van Kooten (2019) looks at the compensation costs to eliminate supply management in dairy based on quota value and producer losses. These models assess Canada as a single market and forego regional differences.

Conversely, Cox and Chavas (2001) developed a spatial model of US dairy that incorporates classified

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<sup>2</sup>The agreement will incorporate a formal review process every six years. This review process will allow for an update of the agreement to include new trade challenges. The agreement will terminate 16 years after entry into force, with the option to renew for an additional 16 years after each six year review.

pricing and a vertically integrated market from producer to consumer.<sup>3</sup> This model was adjusted and applied to the EU dairy market by Bouamra-Mechemache et al. (2002a,b). Abbassi, Bonroy, and Gervais (2008) adapted the model to the Canadian context with nuances of Canada’s supply managed dairy industry including TRQs, farm-level production quota, and support prices. These spatial and vertically integrated models are preferred to the single market models as they allow one to account for the regional rigidities imposed by the supply managed system as well as the incorporation of product specific mechanisms such as price supports. Moreover, these models allow us to regionally and within supply chain decompose trade agreement effects. Most importantly, the three regions reflect the subtlety of regional dairy pools and their role in classified pricing.

We build on the above literature to develop our economic model of the Canadian dairy industry which incorporates current nuances such as Class 7 pricing and imported Milk Protein Concentrates (MPC). Our partial-equilibrium model is calibrated to the 2016/17 dairy year when Class 7 was incorporated into the Canadian dairy sector. The model is composed of three Canadian regions, connected through inter-regional trade and linked to the rest of the world through international trade. Classified pricing allows for the breakdown of raw milk into components and priced depending upon end-use class in the regional production of processed goods, including imported MPCs. Support prices are incorporated to mimic mechanisms to stabilize prices within the market. A two tiered system of tariffs allows for the incorporation of TRQs. Our model is a constrained optimization problem in which a single objective function maximizes social surplus subject to constraints. Constructing the model in this way allows for the movement of components to the most beneficial area of production.

We consider dairy liberalization from CETA, CPTPP, and CUSMA individually and in aggregate at year six which accounts for the vast majority of increases in minimum access commitments. CETA has a six year implementation period with subsequent years remaining fixed. CPTPP and CUSMA have 19 year implementation periods but the first six years account for the bulk of the increases in minimum access commitments; subsequent years observe a 1% compounded increase until year 19 at which point the TRQ remains constant. Further, this six year time period allows for the incorporation of product demand changes ranging from 0% to +3.5% per year for concentrated milk and specialty cheese respectively.

The manuscript is structured in six parts. Section two discusses how the model incorporates the institutional drivers (e.g. component pricing; trade flows; TRQs, etc.) of the Canadian dairy industry. Section three outlines our dairy model. Section four presents the data and calibration of the model to the 2016/17 dairy year. Section five outlines the trade simulations with results of the trade liberalization scenarios com-

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<sup>3</sup>We maintain the term spatial in reference to this inter-regional trade model, as per this literature. We recognize that it differs from the standard definition within spatial economics and econometrics.

pared to the calibrated baseline year. Section six concludes with the implications of these trade liberalization results on the Canadian dairy sector.

## 2 Institutional Drivers of the Model

Institutions shape economic behaviour and thus prior to building our model of Canada's dairy industry we discuss the institutions that need to be considered and appropriately modelled. Canada's supply managed dairy industry is built on a foundation of restricting supply, in the form of production and imports, to meet demand. This system operates to decrease producer price volatility and surplus production so as to maintain a producer price at cost of production. This regulatory environment is maintained by the Canadian Dairy Commission (CDC) who sets market sharing quota limits for dairy producers. It is this constraint on production that creates a gap between the producer price and the perfectly competitive price.

The raw milk from producers is sold to a regional dairy pooling board. These regional milk pools maintain the unit price producers receive through the pooling of revenue. Revenue is generated from the sale of raw milk components to processors at prices dependent on end use product class, known as classified pricing. Classified pricing adjusts component prices based on the cost of production and consumer price index (CPI). Revenue from the sale of components is pooled so all producers within a region receive the same unit price for raw milk.

The breakdown of primary milk into components has allowed for greater flexibility in the production of goods, but has had some not so unexpected consequences given the fixed proportions issue. First, demand for butterfat has far exceeded the demand for protein and other solids leading to importing excess butter outside of TRQ to meet demand. In addition, excess protein and other solids components are diverted into low value animal feed and has caused Canada to reach its SMP drying capacity. The second consequence has been the development of milk protein concentrates (MPC), which are not subject to tariffs. MPCs were imported into Canada as it was cheaper to reconstitute imported MPC components than to purchase domestic protein from regional dairy pools. This resulted in the development of Class 7. Class 7 prices domestic protein in SMP and animal feed at the minimum of three world prices. This SMP is then able to be used as an ingredient in specific products (up to a given proportion).

In addition to maintaining supply, the CDC exerts its' mandate by maintaining price supports on certain products. The price support is used to ensure a stable price on butter and SMP by minimizing seasonal fluctuations.<sup>4</sup> To maintain the system, the CDC purchases goods at the support price when there is excess

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<sup>4</sup>Since the development of Class 7 in 2017 the CDC no longer maintains the support price on SMP. In that same year the CDC sold off its SMP inventory primarily to the animal feed market. The support price is still published but the maintenance of the support price through the seasonal purchasing and selling of SMP is no longer enforced (Canadian Dairy Commission,

supply. These goods are maintained in inventories and sold back into the market when there is excess demand; that is, when the market price is above the support price.

To limit the amount of imports a series of TRQs have been established with two-tiered tariff rates. TRQs were incorporated under the Uruguay Round’s elimination of non-tariff barriers and the tariffication of import quota limits. TRQ is a minimum access commitment that allows products to be imported at an in-quota tariff rate. Above that minimum access commitment the product may be imported at an over-quota tariff rate. The over-quota tariff rate is set at a prohibitively high level with probability approaching one in many cases. Minimum access commitments are allocated according to a licensing system through an application to Global Affairs Canada.

The final institutional driver included in our model is annual changes in consumer demand for dairy products. Trade liberalization takes place over a period of time during which demand can change significantly; incorporating these demand changes in conjunction with the increased market access commitments offers a more realistic assessment of impacts to the dairy sector.

### 3 Dairy Model

This section outlines our model and closely follows the underpinnings of Cox and Chavas (2001) and Abbassi, Bonroy, and Gervais (2008). Let  $i = 1, \dots, I$  denote Canadian regions,  $k = 1, \dots, K$  denote products, and  $s = 1, \dots, S$  denote components. The model has  $I = 3$  regions: western Canada, Ontario, and eastern Canada. We denote  $W$  as the rest of world. The  $K = 10$  processed products are butter, cheddar cheese, pizza mozzarella cheese, specialty cheese, fluid milk, concentrated milk, ice cream, yogurt, animal feed, and skim milk powder. MPC is included as an 11th product.  $MPC_i$  is imported from the international market and broken down into its components to be used in the production of specific Canadian products. The  $S = 3$  components used in the production of processed goods are butterfat, protein, and other solids.

Our objective function can be interpreted as a quasi-welfare function. The objective function maximizes social surplus, the aggregate of consumer and producer surplus:  $\sum_{i=1}^I [D_i(Z_{i1}, \dots, Z_{iK}) - S_i(Q_i) - G_i(X_i, Y_{i1}, \dots, Y_{iK})]$ . The bracketed term indicates the welfare in each regional dairy market. The cost of producing raw milk,  $S_i(Q_i)$ , and the cost to produce processed goods,  $G_i(X_i, Y_{i1}, \dots, Y_{iK})$ , are subtracted from consumer utility,  $D_i(Z_{i1}, \dots, Z_{iK})$ . This regional welfare is then aggregated to give total welfare in the absence of trade. We expand the objective function through a series of additional components and constraints. This expansion will sequentially follow from farm-level production of raw milk to consumption of processed goods.

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2017a). As such the SMP support price is not used in this model.

Let  $Q_i$  be the primary farm level production of raw milk in region  $i$ . The cost of production uses the inverse supply function,  $S_i(Q_i) = \int_0^{Q_i} p_i^S(q) dq$ . The inverse supply function assumes that costs are linear, concave, and that the marginal cost of production equals the price of raw milk which is greater than 0 ( $\partial S_i(Q_i)/\partial Q_i = p_i^S > 0$ ). Regional production is constrained by Canada's system of supply management to a level less than or equal to its market sharing quota ( $MSQ_i$ ). That is,

$$MSQ_i \geq Q_i. \quad (1)$$

In addition to limiting how much raw milk can be produced, Canada's system of supply management restricts the movement of raw milk between provinces. Processors must produce goods in the same region as the raw milk is produced. The purchase of raw milk by regional milk pooling organizations is denoted  $X_i$ . The amount of milk purchased is constrained by the amount of primary raw milk produced within that region. That is,

$$Q_i \geq X_i. \quad (2)$$

The production of processed goods requires the transformation of raw milk purchased by milk pools into components. Raw milk is assumed to have a fixed composition of components denoted by  $\alpha_{is}$ . Similarly, the composition of processed goods are produced subject to a Leontief technology such that a product is composed of components at a fixed regional rate,  $b_{iks}$ . The model assumes there is no free disposal of components. This requires that the composition of all processed products  $Y_{ik}$  produced in a region be constrained by the amount of primary components available within that region. That is,

$$X_i \alpha_{is} \geq \sum_{k=1}^K Y_{ik} b_{iks}. \quad (3a)$$

Our model incorporates both inter-regional and international trade to allow for the movement of processed goods across regions. Before discussing trade of goods, we incorporate imported MPC in the production of specific products. The importation of MPC as an ingredient adjusts the constraint such that the components from imported MPC are used in addition to regionally produced components. MPC is also assumed to be composed of components at a fixed ratio,  $\alpha'_{is}$ . That is,

$$X_i \alpha_{is} + MPC_i \alpha'_{is} \geq \sum_{k=1}^K Y_{ik} b_{iks}. \quad (3b)$$

The amount of imported MPC allowed in a product is limited by regulations on minimum proportion of domestic protein,  $h_{iks}$ . The model incorporates these regulations by binding the proportion of domestic

component in a product,  $M_{iks}$ . The variable is bound between the minimum domestic proportion and 1, that is  $h_{iks} \leq M_{iks} \leq 1$ . The remaining proportion of non-domestic component is by default  $1 - M_{iks}$ .

The cost to produce processed goods is composed of three parts: (i) the transformation of raw milk into components; (ii) the cost of components; and (iii) all other input costs. These regional production processing technologies result in a multi-output restricted cost function,  $G_i(X_i, Y_{i1}, \dots, Y_{iK})$ . This function is the cost minimizing transformation of raw milk purchased by processors, along with other non-milk inputs, into the production of goods  $\sum_{k=1}^K Y_{ik}$ . We assume this is a linear function, decreasing in  $X_i$ , and increasing in  $Y_{ik}$ . That is,  $\partial G_i / \partial X_i > 0$  and  $\partial G_i / \partial Y_{ik} < 0 \forall k = 1, \dots, K$

Trade flows allow for a good produced in one region to be consumed in another. The consumption of goods in a Canadian region, denoted by  $Z_{ik}$ , is composed of products sourced from Canadian and international regions. Inter-regional trade,  $t_{ijk}$ , occurs when a product is traded from one Canadian region and consumed in another. Movement between Canadian regions has a cost  $c_{ijk}$ . Note,  $t_{iik}$  indicates goods consumed in the same region they are produced and thus  $c_{iik} = 0$ .

International imports into Canada are subject to TRQs. The two-tiered system of tariff rates establishes within quota rates,  $\tau_k^{IQ}$ , and over-quota rates,  $\tau_k^{OQ}$ . The quantity of each good imported into Canada at the within quota tariff rate is limited by Canada's market access commitment,  $MAC_k$ . Within quota imports are subject to a licensing system in which the proportion of licenses held in a region are denoted by  $\rho_{ik}$ . Once imported, the product does not necessarily need to be consumed in the same region that it was imported into. The consumption of within access imports,  $TMAC_{ijk}$ , is the quantity of good imported into region  $i$  and consumed in region  $j$ , with the sum of within quota imports constrained by Canada's market access commitments:

$$\rho_{ik} MAC_k \geq \sum_{i=1}^I TMAC_{ijk}. \quad (4)$$

Imports of any good above the market access commitment are subject to a substantially higher over-quota tariff rate that varies with the product. This tariff rate aims to be prohibitively high to limit the amount of imported goods coming into the Canadian market place. Over-quota imports,  $T_{ik}^{OQ}$  do not require a license and are imported directly into the region that demands them. Canadian production exceeding local demand can be exported into the world market, denoted by  $TX_{ik}$ . International trade, both imports and exports, incur a transportation cost of  $c_{W_{ik}}$  between the world market and the trade region.

Canada maintains a system of support prices to balance seasonal fluctuations in supply and demand. The imposition of this dynamic process is difficult given the static nature of our model. Price supports are incorporated using the experience of the base year and are constrained to this pre-liberalization level.  $TG_{iGk}$ , is the quantity of good  $k$  purchased by the CDC at support price  $p_{Gk}$ .  $TC_{Gik}$  is the quantity of CDC

inventory sold back into the market. Given that the price support triggers when the import price is below the support price, the support price operates as a deficiency payment to processors. As this price support is trade distorting, subject to Canada's obligations to the WTO, Canada has agreed not to exceed a certain level of export subsidization. Accordingly, the CDC sells inventories back in to the Canadian market at the world price,  $p_{Wk}$ .

The quantity of goods purchased and sold by the CDC are subject to a series of constraints. First, sales from the CDC cannot exceed the amount of inventory held. Let,  $Y_{Gk}$  be the quantity of inventory held by the CDC. The quantity of inventory sold to consumers by the CDC must be less than the total inventory held. That is,

$$Y_{Gk} \geq \sum_{i=1}^J TC_{Gik}. \quad (5)$$

Given that trade liberalization is likely to affect price, a constraint is included that limits how much the CDC can purchase from processors. The quantity of product purchased by the CDC before trade liberalization,  $\bar{Y}_{Gk}$ , must be greater or equal to the quantity of dairy product purchased by the CDC after trade liberalization. Including this constraint mandates that the CDC's intervention in the dairy industry is limited to its' pre-liberalization levels. Thus,

$$\bar{Y}_{Gk} \geq \sum_{i=1}^J TG_{iGk}. \quad (6)$$

The above restrictions combine to give an objective function that maximizes social surplus within a competitive, but restricted, Canadian dairy market. Regional consumer utility is measured by the consumption of products using the inverse demand function  $D_i(Z_{i1}, \dots, Z_{iK}) = \sum_{k=1}^K \int_0^{Z_{ik}} p_{ik}^d(q_{ik}) dq$ . Let  $p_{ik}^d(Z_{ik}) = 1/m_{ik}(Z_{ik} - b_{ik})$  be the inverse demand function in which the intercept is positive ( $b_{ik} > 0$ ), and the slope is decreasing ( $m_{ik} < 0$ ). The model assumes the consumer utility function is linear, concave, and that the marginal benefit from consuming one more good is equal to its' price and is positive. That is,  $\partial D_i(Z_{ik})/\partial Z_{ik} = p_{ik}^D > 0$ .

The final constraints in the competitive dairy model are market clearing conditions:

$$Y_{ik} \geq t_{ijk} + TX_{iWk} + TG_{iGk} \quad (7)$$

$$Z_{ik} \leq t_{jik} + TMAC_{jik} + T_{ik}^{OQ} + TC_{Gik}. \quad (8)$$

Note, equation 7 states the amount of goods produced in a region must be no less than the amount purchased. Similarly, equation 8 states the amount of goods consumed in a region must be no greater than the amount

of goods purchased by that region. We assume there is not free disposal of goods, implying that these constraints are binding. That is,

These components create a spatial model which solves for the competitive allocation of resources subject to resource constraints (Samuelson, 1952; Takayama and Judge, 1971). Our objective function maximizes social surplus:

$$\begin{aligned}
& \sum_{i=1}^J [D_i(Z_{i1}, \dots, Z_{iK}) - S_i(Q_i) - G_i(X_i, Y_{i1}, \dots, Y_{iK})] - \sum_{i=1}^J \sum_{j=1}^J \sum_{k=1}^K t_{ijk} c_{ijk} \\
& - \sum_{i=1}^J \sum_{j=1}^J \sum_{k=1}^K TMAC_{ijk} (p_{Wk} + c_{Wik} + \tau_k^{IQ} + c_{ijk}) \\
& - \sum_{i=1}^J \sum_{k=1}^K T_{Wik}^{OQ} (p_{Wk} + c_{Wik} + \tau_k^{OQ}) + \sum_{i=1}^J \sum_{k=1}^K TX_{iWk} (p_{Wk} - c_{iWk}) \\
& + \sum_{i=1}^J \sum_{k=1}^K TG_{iGk} p_{Gk} - \sum_{i=1}^J \sum_{k=1}^K TC_{Gik} p_{Wk} \\
& + \sum_{i=1}^J PW_i X_i - \sum_{i=1}^J \sum_{k=1}^K PW_{ik} Y_{ik}.
\end{aligned} \tag{9}$$

The welfare of the competitive industry starts with the base welfare function, subtracting transportation costs and the outflow of revenue for imports, adding the inflow of revenue from exports, and the transfer of revenue with the CDC for price supported products. The inter-regional transportation costs of processed goods to consumers between Canadian regions is  $\sum_{i=1}^J \sum_{j=1}^J \sum_{k=1}^K t_{ijk} c_{ijk}$ . The outflow of revenue for in-quota imports incorporates the world price ( $p_{Wk}$ ), international transportation costs ( $c_{Wik}$ ), in-quota tariff ( $\tau_k^{IQ}$ ), and the inter-regional transportation cost ( $c_{ijk}$ ), and is  $\sum_{i=1}^J \sum_{j=1}^J \sum_{k=1}^K TMAC_{ijk} (p_{Wk} + c_{Wik} + \tau_k^{IQ} + c_{ijk})$ . Similarly, the outflow of revenue for over-quota imports incorporates the world price, international transportation costs, and over-quota tariff rate ( $\tau_k^{OQ}$ ), and is  $\sum_{i=1}^J \sum_{k=1}^K T_{Wik}^{OQ} (p_{Wk} + c_{Wik} + \tau_k^{OQ})$ . The influx of revenue from the sale of Canadian products into the world market is added into the model through the amount of exports sold at world prices ( $\sum_{i=1}^J \sum_{k=1}^K TX_{iWk} p_{Wk}$ ). The inflow of revenue from the CDC purchasing goods at the support price is measured by the quantity purchased and the support price ( $\sum_{i=1}^J \sum_{k=1}^K TG_{iGk} p_{Gk}$ ). The outflow of revenue to purchase the CDC inventories is measured by quantity purchased and the world price ( $\sum_{i=1}^J \sum_{k=1}^K TC_{Gik} p_{Wk}$ ).

The final component of the model is classified pricing. This adjusts the competitive model to the not perfectly competitive supply managed dairy industry. We follow Cox and Chavas (2001) by incorporating price discrimination. Farm-level producers of raw milk receive revenue  $PW_i X_i$  above the perfectly competitive farm income. This producer revenue is generated through a markup on the sale of processed products,  $PW_{ik} Y_{ik}$ . The additional revenue producers receive is added while the additional costs of purchasing pro-

cessed goods is subtracted. Classified pricing operates as a transfer from consumers to producers. It is assumed that processors operate in a competitive environment resulting in all gains from the price distortion being transferred to producers:

$$\sum_{i=1}^J PW_i X_i = \sum_{i=1}^J \sum_{k=1}^K PW_{ik} Y_{ik} \quad (10)$$

The approach for finding the exogenous price wedges follows the step-wise iterative process proposed by Cox and Chavas (2001). The regional price wedge in the downstream market is chosen based on calibration and combined with the level of primary production constrained by the MSQ. Calibration is also used to recover the regional price wedges of each processed product. This process takes into account the elasticity of demand, market power, and other factors that may impact the demand from the downstream market. The constrained optimization is then run with these price wedges. In the final step we evaluate the outcome of the model compared to the target and adjust the price wedges accordingly. This iterative process is repeated until the model converges to the base line solution. This baseline is meant to establish the non-competitive market equilibrium under price discrimination.

The constrained maximization problem maximizes the objective function (equation 9) subject to constraints (equations 1-8). The Lagrange and Kuhn-Tucker Conditions (KTCs) can be found in the Appendix. Assuming away corner solutions, the Lagrange multipliers give the shadow price for goods within the model. For instance, to find producer price we take the Lagrange multiplier  $\psi_i$  on the constraint  $(Q_i - X_i)$  to find the marginal willingness of processors to pay for an additional unit of raw milk. Similarly, the wholesale price is found through the Lagrange multiplier,  $\beta_{ik}$ , on the production constraint (equation 7).

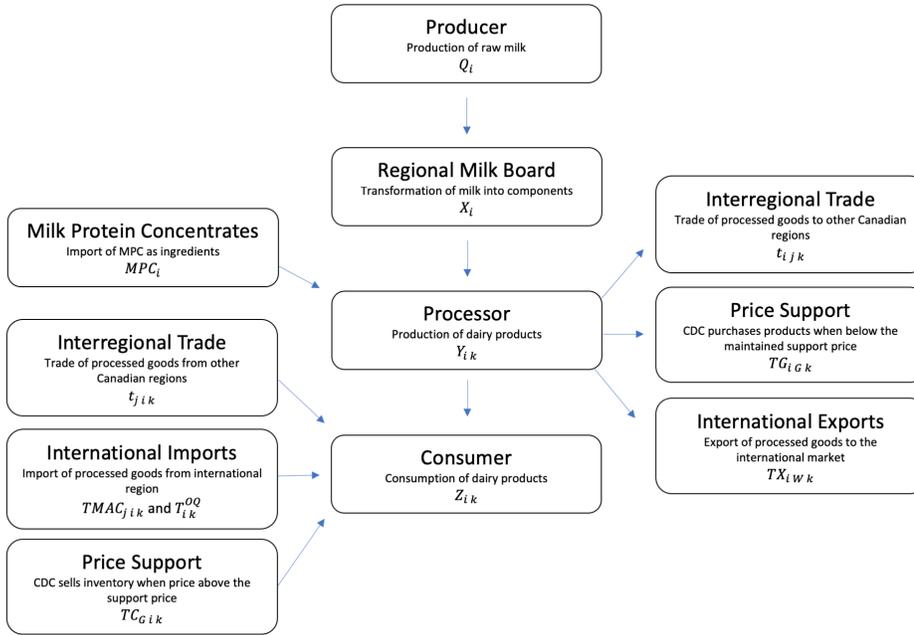
A number of interesting insights can be established by evaluating the KTCs. On the producer, side we find the regional shadow price for raw milk is equal to the revenue from components, minus the cost of transforming raw milk to components, plus the price wedge ( $\psi_i = \sum_{s=1}^S \lambda_{is} a_{is} - \partial G_i / \partial X_i + PW_i$ ). The producer price is also shown to be equal to the marginal cost of production plus the marginal quota value per litre ( $\psi_i = \partial S_i / \partial Q_i + \delta_i$ ). Given that  $\lambda_{is}$  is the shadow price for components, the wholesale price for a processed good is equal to the cost of components, the marginal cost of processing for non-milk inputs, plus the price wedge ( $\beta_{ik} = \sum_{s=1}^S \lambda_{is} b_{iks} + \partial G_i / \partial Y_{ik} + PW_{ik}$ ). For consumers, the KTCs indicate that the shadow price of a product is equal to the marginal utility they receive from that product ( $\chi_{ik} = \partial D_{ik} / \partial Z_{ik}$ ).

The arbitrage condition indicates the price relationship when consumer demand initiates imports. The in-quota market access limits are filled if consumers willingness to pay for one more unit of product is equal to the world price, transportation costs, the in-quota tariff, and the marginal willingness to pay for another imported good ( $\chi_{ik} = p_{Wk} + c_{Wik} + c_{jik} + \tau_k^{IQ} + \eta_{ik}$ ). If there are over-quota imports, the price relationship indicates consumers willingness to pay is equal to the world price, transportation costs, and the over-quota

tariff ( $\chi_{ik} = p_{Wk} + c_{Wik} + c_{jik} + \tau_k^{OQ}$ ). Combined, this illustrates that if there are imports above the MAC that over-quota imports will increase until the willingness to pay for one more imported good is equal to the difference between tariff rates ( $\eta_{ik} = \tau_k^{OQ} - \tau_k^{IQ}$ ).

In Figure 1 we graphically illustrate the structure of our dairy model. This figure outlines the supply chain of the Canadian dairy sector. Farm level production of milk is purchased by regional milk boards, who sell components to processors. Processors produce goods and sell them regionally and internationally. The CDC purchases products and sells inventory to maintain a support price. Consumers are able to purchase goods from all Canadian regions and the international market to maximize their utility.

Figure 1: Supply Chain and Linkages of the Dairy Sector



## 4 Data and Calibration

To calibrate the model a few assumptions are needed regarding parameters. The linear consumer demand function,  $p_{ik}^d = 1/m_{ik}^d(q_{ik}^d - b_{ik}^d)$ , requires estimates of the slope and intercept parameters, solved for using base year data. The slope is calculated by multiplying the own-price elasticity of demand by target consumption divided by the target retail price of each product,  $m_{ik}^d = \epsilon^d Q_{ik}^*/p_{ik}^*$ . The intercept is calculated through an elementwise multiplication of target quantity subtracting slope multiplied by the target retail price,  $b_{ik}^d = Q_{ik}^* - m_{ik}^d P_{ik}^*$ . The model uses Canadian dairy elasticities of demand from (FAPRI, 2018) for butter

(-0.4), cheese (-0.23), and fluid milk (-0.17).<sup>5</sup> Veeman and Peng (1997) calculated dairy demand elasticities for ice cream (-0.62), yogurt (-0.81), and concentrated milk (-0.78). Finally, an elasticity of demand of -1 was used for both animal feed and SMP (Moschini and Moro, 1993).

Our processed products belong to a Canadian class with associated component prices (see Table 1). Wholesale and retail prices proved difficult to obtain on a regional basis. Retail prices for butter and cheese are taken from the CDIC; cheese has a regional breakdown of prices while butter has only a national price. Personal contact with Agriculture and Agri-Food Canada (AAFC) provided regional retail prices for 2013/14. The prices for yogurt, ice cream, animal feed, SMP were updated to the 2016/17 baseline using the CDIC Consumer Price Index and the Industrial Product Price Index. Concentrated milk and fluid milk are from Statistics Canada Monthly Average Retail Price data. To account for heterogeneity across regions, the data was adjusted based off previous ratios from 2013/14. All prices were verified by AAFC. The wholesale price for products was imputed through an approximate retail/wholesale mark-up, with adjustments depending upon component input costs. Regional consumption was found using per capita consumption data combined with Statistics Canada population estimates.

The estimation of the producers cost function,  $S_i(Q_i)$ , begins with the calculation of the producer supply function,  $p_i^s(Q_i)$ . The producer supply function is integrated to find the regional producer costs of producing milk,  $S_i(Q_i) = \int_0^{Q_i} p_i^s(q_i^s) dq_i^s$ . The producer supply function is assumed to be linear with a supply elasticity of  $\epsilon^s = 1$  (Meilke, Sarker, and Le Roy, 1998; Abbassi, Bonroy, and Gervais, 2008; Rude and An, 2013). The marginal cost of production,  $MC_i$ , is estimated to be the total cash component in Canadian cost of production surveys (Cairns and Meilke, 2012; Meilke, Sarker, and Le Roy, 1998). The regional marginal costs of production are \$43.73 in Western Canada (Alberta Agriculture and Forestry, 2017), \$41.60 in Ontario (Ontario Dairy Farm Accounting Project, 2017), and \$41.92 in Eastern Canada (Canadian Dairy Commission, 2017b). These marginal costs are slightly higher but in regional alignment with previous studies (Abbassi, Bonroy, and Gervais, 2008; Meilke, Sarker, and Le Roy, 1998). Regional farm milk price, production, and quota levels were obtained from CDIC.

The processor cost function,  $G_i(X_i, Y_{i1}, \dots, Y_{i10})$ , is composed of the cost of transforming raw milk into components and the cost of producing products:

$$G_i(X_i, Y_{i1}, \dots, Y_{i10}) = g_i X_i + \sum_{k=1}^K g_{ik} Y_{ik}. \quad (11)$$

The multi-output cost function is assumed to be linear in all arguments (equation 11). The transformation

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<sup>5</sup>Bouhhal, Capps, and Ashdorj (2013) found that cheese types similar to those used in this model had similar elasticities based on American panel data. These price elasticities of demand ranged between -0.224 and -0.246.

cost,  $g_i$ , is taken from Bouamra-Mechemache et al. (2002a). This cost, €0.02, is converted to Canadian dollars using the 2002 exchange rate and inflated using the CPI to a 2017 amount of \$0.039 per litre. Processors' marginal costs of production are calculated using the first order condition of the Lagrangian with respect to the processed good (equation 12). The marginal cost of production is approximated as the wholesale price minus the price wedge and the cost of components,  $g_{ik} = \beta_{ik} - PW_{ik} - \sum_{s=1}^S \lambda_{is} b_{iks}$ .

$$\begin{aligned} \partial L / \partial Y_{ik} &= -g_{ik} - PW_{ik} + \beta_{ik} - \sum_{s=1}^S \lambda_{is} b_{iks} \leq 0 \text{ for } Y_{ik} = 0 \\ &= 0 \text{ for } Y_{ik} > 0 \end{aligned} \tag{12}$$

The proportion of component in processed products,  $b_{iks}$ , are taken from Canadian Dairy Commission (2018). The imported MPC used as ingredients are assumed to be MPC80, referring to their 80% Protein content (Dairy Management Inc, 2003). Component pricing is set by provincial milk marketing boards with revenue from component sales pooled through regional milk pooling organizations. The Western Milk Pool covers all provinces west of and including Manitoba. The P5 Agreement (Agreement on Eastern Canadian Milk Pooling) includes all provinces east of and including Ontario except Newfoundland and Labrador (BC Milk Marketing Board, 2016; Dairy Farmers of Ontario, 2018). As processors are charged for milk components based on end use component pricing each product is assigned to a product classification (see Table 1).

Table 1: Product Class

Product	Class
Butter	4(a)
Cheddar Cheese	3(b)
Pizza Mozzarella Cheese	3(d)
Specialty Cheese	3(c)
Fluid Milk	1(a)
Concentrated Milk	4(b)
Ice Cream	2(b)
Yogurt	2(a)
Animal Feed	4(m)
Skim Milk Powder	7

*Source: CDC.*

Special consideration of within component pricing is needed for Class 7. Through the current Class 7 system a producer is charged for the minimum amount of domestic content at the class price for components. The remaining proportion is charged at Class 7 price regardless of the amount of MPC ingredients. Equation 13 indicates the component costs, in which  $\lambda_{iks}$  refers to the product class component price and  $\lambda_{i10s}$  refers

to the Class 7 component price for SMP.

$$\lambda'_{is} = h_{iks}\lambda_{iks} + (1 - h_{iks})(\lambda_{i10s}) \quad (13)$$

Transportation costs for inter-regional trade within Canada uses the driving distance between the main cities within each region, and averaged for regions with more than one major city. These distances are coupled with a transportation cost of USD\$0.35 per hundredweight per 100 miles as used in Cox and Chavas (2001). This value is converted to CA\$/kg per km using Statistics Canada’s exchange rate and adjusted for inflation using Statistics Canada’s Transportation Cost Index, with an end price of \$0.0000979 CAD/kg per km. International transportation costs are calculated as the difference between the unit import value and unit export value for each product (Abbassi, Bonroy, and Gervais, 2008). The in-quota tariff rates ( $\tau_k^{IQ}$ ) and over-quota rates, ( $\tau_k^{OQ}$ ) are collected from the Canada Border Services Agency’s 2017 customs tariff schedule.

Table 2: In-Quota and Over-Quota Tariffs

Product	In-Quota Tariff(%)	Over-Quota Tariff(%)
Butter	6.5	298.5
Cheddar Cheese	1.0	245.5
Pizza Mozzarella Cheese	1.0	245.5
Specialty Cheese	1.0	245.5
Fluid Milk	7.5	241.0
Concentrated Milk	1.6	259.0
Ice Cream	6.5	277.0
Yogurt	6.5	237.5
Animal Feed	0.0	0.0
Skim Milk Powder	6.5	270.0
Milk Protein Concentrate	0.0	0.0

*Source: Global Affairs Canada.*

To assess impacts of scenarios that happen over a period of time annual changes in consumer demand are incorporated. These changes act to shift the consumer demand function of each product, effectively taking into account Canada’s annual 1% population growth rate and evolving consumer preferences (Statistics Canada, 2018). These product demand changes are incorporated on an annual, compounded basis. The target quantity in each region is multiplied by the demand change to the power of the number of years in the period,  $Q_{ik}^{**} = Q_{ik}^*(1 + \Delta_k^d)^{yr}$ . This demand change is introduced into the counterfactual adjusting the intercept,  $b_{ik}^d = Q_{ik}^{**} - m_{ik}^d P_{ik}^*$ , and thus shifting the demand function outward(inward) for an increase(decrease) for that product. The associated annual product demand changes are butter 3%, cheddar cheese 2%, pizza mozzarella cheese 2%, specialty cheese 3.5%, fluid milk 1%, concentrated milk 0%, ice cream 2%, yogurt 1%,

animal feed 3%, and SMP 2%.<sup>6</sup> The increase in animal feed and SMP are the byproduct of growth on the other high value products with these two goods absorbing the excess protein and other solids. It should be noted that when these demand changes are incorporated, all other parameters, including MSQ, remain fixed and constant.

The calibration of a constrained optimization model is associated with a number of issues, not least of which when applied to a supply managed industry. First, an issue within this model is that it optimizes to find the social surplus maximizing production and allocation of goods. This allocation is calibrated to the supply managed dairy sector which is innately sub-optimal given its restrictions on supply, both domestic and international. Second, the inclusion of animal feed, a product developed to absorb excess protein and other solid components, required adjustment to act as a slush variable for excess protein and other solid components in the model to operate similar to what happens in the marketplace. Finally, the model weights producer surplus and consumer surplus equally in social surplus. In reality, producer surplus receives a greater weight as it is the preservation of domestic producer welfare that the system of supply management aims to uphold at the expense of consumer access to dairy products at world prices.

## 5 Trade Simulations

We consider six different trade scenarios: CETA; CPTPP; CUSMA; CUSMA with the removal of Class 7; the aggregate impact of the three Regional Trade Agreements (RTAs); and, the RTAs with the removal of Class 7.<sup>7</sup> The market access commitments are outlined in the agreements on Global Affairs Canada website. These commitments are incorporated based on their overlap with products in the model. We first run a baseline scenario to which all trade liberalization scenarios are compared. These scenarios incorporate the additional market access commitments and the change in demand over the six year implementation period. The model is re-optimized for each scenario and results are compared to the baseline to assess impacts. We summarize the MAC by scenario in Table 3.

The CUSMA and RTAs scenarios have two additional features beyond the MAC in Table 3. First, there are export limits on SMP and infant formula. The export limit on SMP is set at 35,000 metric tonnes with a \$0.54 per kg charge applied above that limit. infant formula has an export cap of 40,000 tonnes and a \$4.25 per kg charge applied above that limit. For SMP, we assume this limit is binding. For infant formula, as this

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<sup>6</sup>The fluid milk change incorporates a 1.5% annual decrease in demand for fluid milk and a 4% increase in demand for cream. Due to the butterfat contents and the level of consumption of these products the change in demand for butterfat within this category is approximately 1%. Communications with DFO resulted in these annual percentage changes.

<sup>7</sup>The main commitments of these agreements are implemented in the first six years of the agreements. CETA has a six year implementation period with no growth afterwards. CPTPP and CUSMA have 19 year implementation periods, but market access commitments increase by 1% annually after year six. This 1% growth approximates Canada's population growth rate, but is less than the growth in demand for most products.

Table 3: Market Access Commitments (mt)

Product	WTO	CETA	CPTPP	CUSMA	RTAs
Butter	3274	-	4500	4500	9000
Cheddar Cheese	3149	1190	6000	4375	11565
Pizza Mozzarella Cheese	1228	510	4875	1875	7260
Specialty Cheese	16035	16000	3625	6250	25875
Fluid Milk	64894	-	50580	60500	111080
Concentrated Milk	11.7	-	2000	1380	3380
Ice Cream	484	-	1051	690	1741
Yogurt	332	-	6000	4135	10135
Animal Feed	-	-	-	-	-
Skim Milk Powder	3425	-	7500	7500	15000

*Note: The MAC are the ones used in this model rather than specifically the ones in the agreements. For instance CETA allows for 1,700 mt of Industrial Cheese imports, which is assumed to be broken down between the cheddar cheese and pizza mozzarella cheese products.*

is a product Canada does not yet export, it is assumed that Canada will export at the limit. To incorporate this export restriction, the respective amount of components are subtracted from the aggregate components available for production, the left hand side of equation 3b.<sup>8</sup> The RTAs with the removal of Class 7 increases Class 7 prices to reflect the SMP pricing formula outlined in the CUSMA agreement. The resulting pricing is in line with, and marginally above, the USDA price.

The six year time period in which the main access commitments are imposed is used in conjunction with the annual consumer demand changes for the various dairy products. These product demand changes are incorporated on an annual basis, compounded over the six year implementation period. The change in demand will shift the consumer demand functions for each product separately. The compounded impact sees the largest demand increase on specialty cheese and butter, 23% and 19% respectively, and the lowest on concentrated milk, 0%. All other parameters, including MSQ, remain fixed and constant.

Table 4 outlines the producer price impacts within each region under the trade liberalization scenarios. It is generally expected that trade liberalization will impose negative pressure on producer prices. The influx of goods available at world prices and in-quota tariffs will decrease demand for domestically produced goods, thereby decreasing demand for raw milk. However, the inclusion of consumer demand changes in this model, along with trade liberalization, results in producer prices increases of 15.0%, 11.9%, and 6.3% for CETA, CPTPP, and CUSMA respectively (**individually not collectively**). These increases indicate that these agreements have market access increases less than the increase in consumer demand for products. Within

<sup>8</sup>It is assumed this restriction was implemented in regards to foreign investment into constructing an infant formula plant in Ontario with the exports of infant formula going to China. The planned capacity of the plant is larger than the export limit. Since signing CUSMA the company has declared that a portion of its production capacity has been delegated to infant formula using goats milk. It is assumed that the export threshold will continue to be filled. The plants location in Ontario will remove components strictly from that region.

CUSMA, producer price is shown to increase by a smaller margin, largely as a byproduct of the export limit on SMP. The aggregate scenario of RTAs shows a 4.7% drop in the willingness to pay of processors for domestic raw milk. The regional distribution of producer price changes are the largest in Eastern Canada, a by-product of Quebec's strong dairy production and processing industry, and the most minimal in Western Canada.

The additional impacts from the removal of Class 7 within CUSMA show an increase in producer price over the CUSMA scenario in which it is maintained. This price increase is associated with the increased revenue from protein and other solids which now receive the higher US price and the assumption that there is no free disposal of components. For this same reason, when Class 7 is removed in the RTAs scenario there is a small price increase compared to the RTAs scenario in which it is maintained. This producer price decrease may be smaller than in the CUSMA removal of Class 7 scenario due to less production changes to high value cheese products and greater market access of all Class 7 products, in which consumption is better able to be met by the aggregate TRQ.

The retail price impacts vary depending upon the amount and type of increased MAC and associated production decisions of processors (see Table 4). The impacts of each agreement separately results in a significant increase in the price of cheese, due largely to demand growth. Cheddar cheese increases the most in price while specialty cheese increases by the least, with specialty cheese having a negligible price decrease in the CUSMA scenario. Concentrated milk, ice cream, yogurt, and animal feed decrease in price within each trade agreement separately. These increases result as consumption of these products increases. Butter experiences a large price increase in each separate agreement due to demand growth, the large butterfat component requirements which are reallocated to the production of other high value, high butterfat composition products (ie. cheese) and static quota. A similarly high demand for butterfat in 2016/17 resulted in the CDC importing 11,200 tonnes of butter and 3,000 mt of butterfat in cream under a special permit outside of TRQ (Canadian Dairy Commission, 2017a). Given the consistently high butter price in these results, a similar permit would be needed to resolve this issue if quota were to remain fixed.

Production changes in response to trade liberalization result as components are redistributed to their most valuable use given consumer demand (see Table 5). The absence of free disposal reallocates components from production decreases to the increased production of other goods. Across all scenarios butter, fluid milk, and SMP decrease in production, while pizza mozzarella, specialty cheese, ice cream, and yogurt all increase in production. Specialty cheese production increases significantly to meet demand, with a small broad increase in cheddar and pizza mozzarella production. The increased production of cheese comes at the expense of decreased butter production. This is due in part to the limitations on butterfat components and the large proportion used in butter production, and in part to the high value and the increased consumer demand

Table 4: Trade Liberalization Price Impacts (% change)

Region	CETA	CPTPP	CUSMA	CUSMA No Class7	RTAs	RTAs No Class7
<i>Producer Price</i>						
Western Canada	15.5	12.1	7.1	10.7	-4.9	-3.1
Ontario	16.4	13.3	7.7	10.3	-6.1	-4.4
Eastern Canada	13.3	10.4	4.4	5.9	-7.4	-6.3
Canada	15.0	11.9	6.3	8.8	-6.2	-4.7
<i>Retail Price</i>						
Butter	28.0	22.4	17.8	27.4	5.2	11.6
Cheddar Cheese	15.3	13.0	9.3	12.2	-1.0	-1.3
Pizza Mozzarella Cheese	10.0	8.4	5.2	6.9	-2.1	-2.7
Specialty Cheese	4.6	2.9	-0.4	1.2	-8.6	-9.4
Fluid Milk	12.7	10.0	5.9	8.0	-4.6	-3.1
Concentrated Milk	-2.4	-4.1	-7.3	-7.9	-9.3	-6.5
Ice Cream	-0.7	-2.4	-7.0	-7.8	-9.7	-9.4
Yogurt	-1.4	-2.1	-5.0	-6.2	-6.8	-7.4
Animal Feed	16.7	16.2	8.8	4.7	-16.7	-17.1
Skim Milk Powder	1.1	1.1	-20.1	-9.9	-24.5	-24.5

for cheese. Similarly, SMP and animal feed production movements are associated with the production of cheese, ice cream, and yogurt which make use of their significant protein composition. There are significant decreases in production of SMP across all scenarios with larger decreases within the CUSMA scenarios, in which there is an export limit on SMP.

Consumption of products broadly increases with trade liberalization through greater access to goods at world prices and in-quota tariffs. The most significant change in consumption is the consistent increase of all cheese types. Cheese consumption increases are similar across CETA, CPTPP, and CUSMA, with a notable further increased consumption in the RTAs scenarios. The contrast between decreases in SMP production and increases in SMP are associated with the export limit in CUSMA. The excess supply of SMP remaining in the Canadian market has an associated large negative impact on its retail price.

Table 6 reports the welfare changes from trade liberalization within each region. Consumer surplus broadly exhibits the expected increases from liberalization and an influx of low tariff dairy products at world prices. The individual trade agreements have increases in producer surplus, as demand for products is larger than increases in TRQs. Social surplus broadly increases across all agreements in conjunction with consumer surplus. This is due to the small number of producers compared to the large number of consumers. These welfare changes will have a more significant individual impact on the small number of producers compared to

Table 5: Trade Liberalization Quantity Impacts (% change)

Product	CETA	CPTPP	CUSMA	CUSMA No Class7	RTAs	RTAs No Class7
<i>Production</i>						
Butter	-6.0	-6.3	-11.1	-10.3	-3.7	-2.5
Cheddar Cheese	2.0	-0.4	2.1	0.8	-0.5	-1.2
Pizza Mozzarella Cheese	3.5	1.1	2.9	3.3	3.0	2.4
Specialty Cheese	6.6	14.1	14.0	13.0	4.8	3.5
Fluid Milk	-2.3	-3.6	-3.3	-3.6	-3.2	-3.5
Concentrated Milk	-3.5	-3.4	0.8	1.5	1.2	2.9
Ice Cream	9.8	11.7	15.7	20.9	19.8	23.9
Yogurt	1.3	0.6	4.2	5.1	4.7	4.9
Animal Feed	-4.3	-3.8	-10.1	-5.5	14.7	18.0
Skim Milk Powder	-0.7	-1.9	-16.8	-21.0	-15.4	-17.6
<i>Consumption</i>						
Butter	-5.8	-1.5	-6.2	-5.4	5.6	6.8
Cheddar Cheese	2.7	3.2	3.9	3.4	6.4	5.6
Pizza Mozzarella Cheese	3.8	4.2	4.8	4.5	6.6	6.1
Specialty Cheese	14.5	14.8	16.0	15.1	18.0	16.8
Fluid Milk	-2.2	-1.8	-1.1	-1.4	0.7	0.5
Concentrated Milk	-3.5	-1.5	2.1	2.8	4.3	6.0
Ice Cream	9.8	12.5	16.2	21.4	21.2	25.2
Yogurt	1.3	2.0	5.2	6.0	7.0	7.3
Animal Feed	-4.3	-3.8	-10.1	-5.5	18.0	20.4
Skim Milk Powder	4.7	4.7	17.6	8.8	21.3	21.3

the smaller individual benefit received by the broad body of consumers. These welfare impacts differ spatially with Eastern Canada, largely driven by Quebec, exhibiting the largest decrease in producer surplus.

With respect to each separate scenario, CETA is interesting as it increases access only to the high value cheese products which exhibit large annual consumer demand growth. The additional cheese access results in the increased consumption of specialty cheese by 14.5%, pizza mozzarella by 3.8%, and 2.7% for cheddar cheese. These consumption increases are below demand growth as prices increase on these products. The increase in cheese TRQ is coupled with cheese production increases of between 2.0% and 6.6%, for pizza mozzarella and specialty cheese respectively. The production increases result from components being diverted from lower value goods, such as animal feed and concentrated milk, as well as the highly valued butterfat in butter. The net increase in producer price across all regions, coupled with a significant increase in butter price, indicates there is still room for quota growth if only CETA commitments were adopted.

CPTPP represents a larger degree of dairy market access on a broader basket of goods. CPTPP resulted in a decrease in production of SMP, animal feed, concentrated milk, fluid milk and butter with components diverted to a 14.1% increase in specialty cheese production and an 11.7% increase in ice cream. Consumption

Table 6: Welfare (% change)

<b>Product</b>	<b>CETA</b>	<b>CPTPP</b>	<b>CUSMA</b>	<b>CUSMA No Class7</b>	<b>All FTA</b>	<b>All FTA No Class7</b>
<i>Western Canada</i>						
Producer Surplus	15.5	12.1	7.1	10.7	-4.9	-3.1
Consumer Surplus	3.0	3.6	4.4	4.2	7.3	6.9
Social Surplus	4.1	4.4	4.6	4.7	6.2	6.0
<i>Ontario</i>						
Producer Surplus	16.4	13.3	7.7	10.3	-6.1	-4.4
Consumer Surplus	3.0	3.6	4.4	4.1	7.2	6.8
Social Surplus	4.3	4.6	4.7	4.7	5.9	5.7
<i>Eastern Canada</i>						
Producer Surplus	13.3	10.4	4.4	5.9	-7.4	-6.3
Consumer Surplus	3.2	3.8	4.6	4.3	7.5	7.0
Social Surplus	5.0	5.0	4.6	4.6	4.9	4.7
<i>Canada</i>						
Producer Surplus	14.8	11.7	6.1	8.4	-6.4	-5.0
Consumer Surplus	3.1	3.7	4.4	4.2	7.3	6.9
Social Surplus	4.5	4.7	4.6	4.7	5.7	5.5

decreases marginally on butter, fluid milk, concentrated milk, and animal feed, with big increases on specialty cheese, 14.8%, and ice cream, 12.5%, linked to production changes. Retail prices increase most on butter, 22.4%; animal feed, 16.2%; and cheddar cheese, 13.0%, with minor price decreases on concentrated milk, ice cream, and yogurt between 2.1% and 4.1%. Producers observe an 11.9% increase in their blend price as demand exceeds the increased new access. This producer price increase results in Canada's producer surplus increasing by 11.7%, compared to a smaller consumer surplus increase of 3.7%.

CUSMA results in the biggest changes of the individual agreements. In the first scenario keeping Class 7 pricing, consumers experience the most significant changes in consumption of specialty cheese, ice cream, and SMP, 16.0-17.6%. There is a notable 16.8% decrease in SMP production, caused by the 35,000 mt export limit, and an 11.1% decrease in butter production. Prices remain largely unchanged on specialty cheese, while cheddar cheese and pizza mozzarella increase by 9.3% and 5.2% respectively as production and increased access fails to meet demand. When Class 7 is removed the production impacts are broadly similar, with the notable changes being the decrease in SMP by 21.0% and ice cream increasing by 20.9% compared to the baseline. Prices increase on cheese products affected by Class 7 compared to CUSMA scenario as the cost of inputs have also increased, while prices decrease on the lower value concentrated milk, ice cream and yogurt as relative production and consumption increase. The increased cost of components from the removal of Class 7 for processors runs through to increase producer price compared to when Class 7 is in effect. The

welfare changes from CUSMA with and without Class 7 indicate producers are made better off from the removal of Class 7, as they now receive a higher price for those components, with producer surplus increasing by 2.3% compared to CUSMA with Class 7.<sup>9</sup> Consumer surplus decreases marginally as the higher cost of production increases retail prices they face. In aggregate, social surplus increases by similar amounts from the implementation of CUSMA with and without Class 7, 4.6% and 4.7% respectively.

The impacts of the RTAs in aggregate indicate there will be large increases in the consumption of all dairy products. The largest increases in consumption are specialty cheese, 18.0%; ice cream, 21.2%; animal feed, 18.0%; and SMP, 21.3%. Production changes are more tempered than in the CUSMA scenarios, with the broad spectrum of TRQ under these RTAs minimizing large production increases into any single product. The increased supply of dairy products decreases retail prices on all goods except for butter, which increases by 11.6% compared to the baseline. SMP has the largest decrease in price at -24.5%, which is the price floor from the USDA SMP pricing formula and equivalent to the US SMP price. The large, broad decrease in retail prices from increased supply of dairy products decreases demand for domestic raw milk. Producer price decreases by 6.2%, resulting in a decrease in producer surplus of 6.4%. Consumers benefit from the supply of lower priced goods, resulting in a welfare increase of 7.3%. The aggregate impact of all these trade agreements results in Canadian social surplus increasing by 5.7%.

The additional removal of Class 7 alongside the incorporation of all trade agreements has trivial impacts compared to when it remains in place. The notable changes include an increase in animal feed production, whose price is not affected by the removal of Class 7 pricing, and a further decrease in SMP production. Producer's blend price observes an increase compared to the RTAs scenario with Class 7. This producer price, which is a similar impact to the CUSMA scenario, results from the increased price received from Class 7 components. The welfare impacts result in producers having higher surplus compared to when Class 7 remains, and consumer surplus decreasing due to higher costs of production being passed on. Notably, now the producer surplus increase is less than the consumer surplus increase, resulting in the removal of Class 7 decreasing social surplus.

## 6 Concluding Remarks

The Canadian dairy industry is facing broad new pressures as Canada continues to pursue freer trade while maintaining its protected industries. Supply management's inclusion in free trade agreements has been a highly contentious issue, especially in dairy, as foreign countries demand access to the protected Canadian market. CETA, CPTPP, and CUSMA increase the supply of in-quota dairy imports through market access

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<sup>9</sup>Removal of Class 7 is simply changing the pricing of SMP from the minimum of three world prices, which included the US price, to the US price. As such this represents a price increase, albeit marginal, to producers.

commitments that have a multi-year implementation period. Concurrently, the Canadian population is expected to grow and consumer demand for dairy products, notwithstanding population growth, is expected to continue increasing for most products. These changes shift the consumer demand functions outward for most dairy goods. The impact of these two counteracting forces, increased demand and supply, result in surprisingly smaller impacts from the trade agreements than may be expected.

Increased market access from trade liberalization results in increased consumption of most dairy products. Each individual agreement indicates consumer demand growth is larger than the respective increased minimum access commitments as evidenced by increases in the producer blended milk price. The aggregate impact of these trade agreements together marginally exceeds consumer demand for most products over the six year implementation period. However, the demand for butter is consistently greater than supply, which could be mediated through an increase in butterfat production or special license butter imports outside of TRQ (as happened in 2016/17). For all other products, the retail price decreases with an aggregate retail price decrease of approximately 7.0%. Similarly, the producer blended price of milk decreases by 4.7%, with the eastern region, composed mainly of Quebec, experiencing the largest producer price decrease.

The impact of removing Class 7 is perhaps surprisingly minimal and in a different direction than generally expected. The product, defined under Class 7 pricing, remains and will be priced at a marginally higher level. That is, will be priced at or above US prices versus at or below US prices. As a result, producers are shown to have an increase in surplus while consumers are slightly worse off. These impacts may be even more muted in reality as there is more likely to be free disposal of excess components that do not generate revenue for producers.

The price and quantity impacts of all trade agreements result in welfare changes to both producers and consumers, with producer surplus decreasing by 5.0% while consumer surplus increases by 6.9%. With producer impacts concentrated in a small population while consumer benefits are shared across a large population, the resulting combined welfare impacts of trade liberalization results in a 5.5% increase in social surplus. As the trade agreements have fixed minimum access commitments, versus proportional increases, the impacts will decrease in severity over time as population and demand continues to grow. The downward pressure on producer surplus could be mitigated through mechanisms to increase component availability thereby sidestepping the fixed proportion constraint.

Finally, our results suggest that CETA, CPTPP, and CUSMA individually or collectively will not undermine supply management in Canada's dairy sector. Conversely, if population growth and changing preferences reverse, however unlikely, our results would be markedly different.

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# A Appendix

## A.1 Lagrangian

The objective function noted earlier, equation 9, serves as the basis of the Lagrangian ( $\mathcal{L}$ ).

$$\begin{aligned}
\mathcal{L} = & \sum_{i=1}^J [D_i(Z_{i1}, \dots, Z_{iK}) - S_i(Q_i) - G_i(X_i, Y_{i1}, \dots, Y_{iK})] \\
& - \sum_{i=1}^J \sum_{j=1}^J \sum_{k=1}^K t_{ijk} c_{ijk} - \sum_{i=1}^J \sum_{j=1}^J \sum_{k=1}^K TMAC_{ijk} (p_{Wk} + c_{Wik} + \tau_k^{IQ} + c_{ijk}) \\
& - \sum_{i=1}^J \sum_{k=1}^K T_{Wik}^{OQ} (p_{Wk} + c_{Wik} + \tau_k^{OQ}) + \sum_{i=1}^J \sum_{k=1}^K TX_{iWk} (p_{Wk} - c_{iWk}) \\
& + \sum_{i=1}^J \sum_{k=1}^K TG_{iGk} p_{Gk} - \sum_{i=1}^J \sum_{k=1}^K TC_{Gik} p_{Wk} + \sum_{i=1}^J PW_i X_i - \sum_{i=1}^J \sum_{k=1}^K PW_{ik} Y_{ik} \\
& + \sum_{i=1}^J \delta_i (MSQ_i - Q_i) + \sum_{i=1}^J \psi_i (Q_i - X_i) + \sum_{i=1}^J \sum_{s=1}^S \lambda_{is} \left( X_i a_{is} + MPC_i \alpha'_{is} - \sum_{k=1}^K Y_{ik} b_{iks} \right) \\
& + \sum_{i=1}^J \sum_{k=1}^K \eta_{ik} \left( \rho_{ik} MAC_k - \sum_{j=1}^J TMAC_{ij} \right) \\
& + \sum_{k=1}^K \gamma_k \left( Y_{Gk} - \sum_{i=1}^J TC_{Gik} \right) + \sum_{k=1}^K \mu_k \left( \bar{Y}_{Gk} - \sum_{i=1}^J TG_{iGk} \right) \\
& + \sum_{i=1}^J \sum_{k=1}^K \beta_{ik} \left( Y_{ik} - \sum_{i=1}^J T_{ijk} - TX_{iWk} - TG_{iGk} \right) \\
& + \sum_{i=1}^J \sum_{k=1}^K \chi_{ik} \left( \sum_{j=1}^J T_{jik} + \sum_{j=1}^J TMAC_{jik} + TC_{Gik} + T_{Wik}^{OQ} - Z_{ik} \right) \\
& + \sum_{i=1}^J \phi_i \left( PW_i X_i - \sum_{k=1}^K PW_{ik} Y_{ik} \right)
\end{aligned} \tag{A1}$$

$\delta_i$  is the Lagrange multiplier of demand for quota giving the unit value within each region.  $\psi_i$  indicates the implicit price of raw milk.  $\lambda_{is}$  is the multiplier for the allocation constraint of components.  $\Omega_{iks}$  is the implicit price for MPC imports.  $\eta_{ik}$  indicates the implicit price for import licenses.  $\gamma_k$  is the consumer benefit for the support price system.  $\mu_k$  is the consumer cost of the CDC maintaining price supports.  $\beta_{ik}$  is the marginal value of output.  $\chi_{ik}$  is the implicit regional market price of dairy products.  $\phi_i$  is the multiplier associated with the constraint on the transmission of the price distortion from processors to producers.

## A.2 Kuhn-Tucker Conditions

The Kuhn-Tucker conditions associated with the above Lagrangian are:

$$\frac{\partial L}{\partial Q_i} = -\frac{\partial S_i}{\partial Q_i} + \psi_i - \delta_i \leq 0 \text{ with strict equality if } Q_i > 0 \quad (\text{A2})$$

$$\frac{\partial L}{\partial X_i} = PW_i - \frac{\partial G_i}{\partial X_i} + \sum_{s=1}^S \lambda_{is} a_{is} - \psi_i \leq 0 \text{ with strict equality if } X_i > 0 \quad (\text{A3})$$

$$\frac{\partial L}{\partial Y_{ik}} = -\frac{\partial G_i}{\partial Y_{ik}} - PW_{ik} - \sum_{s=1}^S \lambda_{is} b_{iks} + \beta_{ik} \leq 0 \text{ with strict equality if } Y_{ik} > 0 \quad (\text{A4})$$

$$\frac{\partial L}{\partial Z_{ik}} = \frac{\partial D_i}{\partial Z_{ik}} - \chi_{ik} \leq 0 \text{ with strict equality if } Z_{ik} > 0 \quad (\text{A5})$$

$$\frac{\partial L}{\partial T_{ijk}} = -c_{ijk} - \beta_{ik} + \chi_{ik} \leq 0 \text{ with strict equality if } T_{ijk} > 0 \quad (\text{A6})$$

$$\frac{\partial L}{\partial TMAC_{ijk}} = -p_{Wk} - c_{W_{ik}} - c_{j_{ik}} - \tau_k^{IQ} + \chi_{ik} - \eta_{ik} \leq 0 \quad (\text{A7})$$

$$\text{with strict equality if } TMAC_{ijk} > 0 \quad (\text{A8})$$

$$\frac{\partial L}{\partial T_{W_{ik}}^{OQ}} = -p_{Wk} - c_{W_{ik}} - \tau_k^{OQ} + \chi_{ik} \leq 0 \text{ with strict equality if } T_{W_{ik}}^{OQ} > 0 \quad (\text{A9})$$

$$\frac{\partial L}{\partial TX_{iWk}} = p_{Wk} - c_{iWk} - \beta_{ik} \leq 0 \text{ with strict equality if } TX_{iWk} > 0 \quad (\text{A10})$$

$$\frac{\partial L}{\partial TG_{iGk}} = p_{Gk} - \beta_{ik} - \mu_k \leq 0 \text{ with strict equality if } TG_{iGk} > 0 \quad (\text{A11})$$

$$\frac{\partial L}{\partial TC_{G_{ik}}} = -p_{Wk} - \gamma_{ik} + \chi_{ik} \leq 0 \text{ with strict equality if } TC_{G_{ik}} > 0 \quad (\text{A12})$$

$$\frac{\partial L}{\partial \delta_i} = MSQ_i - Q_i \leq 0 \text{ with strict equality if } \delta_i > 0 \quad (\text{A13})$$

$$\frac{\partial L}{\partial \psi_i} = Q_i - X_i \leq 0 \text{ with strict equality if } \alpha_i > 0 \quad (\text{A14})$$

$$\frac{\partial L}{\partial \lambda_{is}} = X_i a_{is} - \sum_{k=1}^K Y_{ik} b_{iks} \leq 0 \text{ with strict equality if } \lambda_{is} > 0 \quad (\text{A15})$$

$$\frac{\partial L}{\partial \Omega_{iks}} = M_{iks} - h_{iks} \leq 0 \text{ with strict equality if } \Omega_{ks} > 0 \quad (\text{A16})$$

$$\frac{\partial L}{\partial \eta_{ik}} = \rho_{ik} MAC_k - \sum_{j=1}^J TMAC_{ijk} \leq 0 \text{ with strict equality if } \eta_{ik} > 0 \quad (\text{A17})$$

$$\frac{\partial L}{\partial \gamma_k} = Y_{Gk} - \sum_{i=1}^J TC_{Gik} \leq 0 \text{ with strict equality if } \gamma_k > 0 \quad (\text{A18})$$

$$\frac{\partial L}{\partial \mu_k} = \bar{Y}_{Gk} - \sum_{i=1}^J TG_{iGk} \leq 0 \text{ with strict equality if } \mu_k > 0 \quad (\text{A19})$$

$$\frac{\partial L}{\partial \beta_{ik}} = Y_{ik} - \sum_{i=1}^J T_{ijk} - TX_{iWk} - TG_{iGk} \leq 0 \text{ with strict equality if } \beta_{ik} > 0 \quad (\text{A20})$$

$$\frac{\partial L}{\partial \chi_{ik}} = \sum_{j=1}^J T_{jik} + \sum_{j=1}^J TMAC_{jik} + TC_{Gik} + T_{Wik}^{OQ} - Z_{ik} \leq 0 \text{ with strict equality if } \chi_{ik} > 0 \quad (\text{A21})$$

$$\frac{\partial L}{\partial \phi_i} = PW_i X_i - \sum_{k=1}^K PW_{ik} Y_{ik} \leq 0 \text{ with strict equality if } \phi_{iks} > 0 \quad (\text{A22})$$