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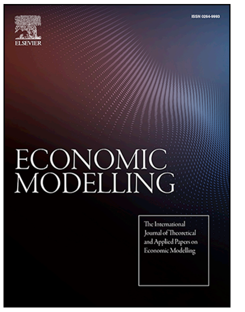

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Properly capturing tariff rate quotas for trade policy analysis in computable general equilibrium models

Yaghoob Jafari[1], Wolfgang Britz[1], Houssein Guimbard[2], Jayson Beckman[3]

[1]Institute for Food and Resource Economics (ILR), University of Bonn, Germany

[2]CEPII (Centre d'Etudes Prospectives et d'Informations Internationales), Paris, France

[3]Economic Research Service, United States Department of Agriculture (USDA)

Abstract

Computable general equilibrium (CGE) models are generally used to conduct trade policy analysis; however, given the complexity in data collection and modeling, tariff rate quotas (TRQs) are often simplified in these models. However, TRQs are crucial for trade negotiations because they are rarely completely liberalized and often the obstacles to negotiations. We propose an approach to model TRQs explicitly and at the product level within CGE models and compare with previous approaches that considered an explicit (or implicit) representation at the tariff line or sector level. Using the Canada–EU trade agreement as an example, we find significant aggregation bias if TRQ shocks are implemented at the aggregate sectoral level. This bias is only partially eliminated if TRQs are implicitly represented by *ad-valorem* equivalents at the tariff line. Our findings suggest the need to represent TRQs explicitly at the relevant commodity detail in trade impact assessments.

Corresponding author: Yaghoob Jafari (Yaghoob.jafari@ilr.uni-bonn.de), Institute for Food and Resource economics, University of Bonn, Bonn, Germany.

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Full postal address of authors:

Yaghoob Jafari
Institute for Food and Resource Economics, University of Bonn
Nussallee 21, D-53115 Bonn
E-mail: yaghoob.jafari@ilr.uni-bonn.de

Tel: ++ 49 – (0)2 28 - 73 25 02

Wolfgang Britz
Institute for Food and Resource Economics, University of Bonn
Nussallee 21, D-53115 Bonn
E-mail: wolfgang.britz@ilr.uni-bonn.de
Tel: ++ 49 – (0)2 28 - 73 29 12

Houssein Guimbard
CEPII (Centre d'Etudes Prospectives et d'Informations Internationales)
20 avenue de Ségur, TSA 10726,
75334 Paris cedex 07, France
E-mail: houssein.guimbard@cepii.fr

Jayson Beckman
Economic Research Service, USDA
355 E Street SW
Washington, DC 20024-3221
E-mail: JBECKMAN@ers.usda.gov

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Keywords: free trade agreements, CETA explicit and implicit modeling of TRQs, tariff line analysis, computable general equilibrium.

JEL: F10, F11, F14, F17

1. Introduction

To estimate the trade and welfare impacts associated with the implementation of free trade agreements (FTAs), computable general equilibrium (CGE) models are generally used because of their ability to capture intersectoral and global bilateral linkages. However, CGE models are often based on simplifications and special assumptions necessary to be tractable, thereby creating a context considered as rather artificial because of the oversimplified representation of policy changes, including insufficient product detail (Junior and Galvão, 2008). In terms of trade policy and FTAs, one aspect typically simplified is the representation of trade policies through *ad-valorem* equivalents (AVEs), which is an attempt to express import instruments through a single percentage of the value of the commodity.[1] As such, important information, particularly with respect to tariff rate quotas (TRQs) under liberalization, could be overlooked.[2] Another aspect relates to the implementation of TRQs at an aggregate sectoral level. Here, detailed products might be subject to an aggregate TRQ where the initial TRQ regimes differ across products or some products are even not traded under a TRQ regime. Furthermore, substitution possibilities in trade between detailed products are ignored. Therefore, TRQ liberalization experiments often result in an ill-posed implementation of policy shocks.

Countries often use TRQs in FTAs to protect domestic producers against foreign competition, typically where applied most favored nation (MFN) tariffs remain high (Beckman et al., 2017).[3] TRQs are primarily used in agri-food sectors (a few exceptions, such as textiles, exist), thereby mirroring that agriculture remains the most protected sector worldwide. Various attempts have been made to properly account for TRQs' specificity in CGE modeling; however, problems relating to both modeling and data deficiencies remain.

[1] More thoroughly, AVEs express the combined impacts of all considered trade policy instruments on a commodity as a percentage tariff levied using the Cost Insurance Freight (c.i.f) price, typically first calculated at the level of individual tariff lines, and afterward aggregated to the sectoral detail in the CGE model.

[2] The conversion of the TRQ to an AVE eases and facilitates their implementation in global CGE models by summarizing information on In-Quota-Tariff Rates (IQTRs), Out-Quota-Tariff Rates (OQTRs), and fill rates (i.e., the import quantity over predetermined quota (Narayanan et al., 2012)). Determining the AVE of a TRQ after liberalization requires, however, an assumption about the future fill rate, which is endogenously modeled under the explicit approach.

[3] TRQs are granted to either a single country in a bilateral trade agreement (Bilateral-TRQs), a group of countries (FTA-TRQs), or to all countries (Erga Omnes-TRQs).

This study introduces a methodological approach, an endogenous TRQ aggregator within the CGE model, where TRQs can be implemented explicitly at any level of product or tariff line details. This methodological approach allows for endogenous switches in the tariff regime, for implementing shocks to relevant products, and to consider substitution across detailed products, thereby preventing bias from both aggregation (commodity and shock aggregation) and neglecting the TRQ mechanism. To address the possibility of these biases, this study first compares the results of two standard approaches to modeling TRQs at the aggregate sector level: their implicit treatment based on AVEs by using the so-called MAcMap approach and their explicit modeling that endogenously captures the regime shift from a low to high tariff when imports exceed the authorized quantity by using a mixed complementarity programming (MCP) approach (e.g., Beckman and Arita, 2017). Second, this study compares the results of representing TRQs at some aggregated sector with their implementation at detailed product (i.e., tariff line) levels.

An explicit TRQ regime in the CGE model requires either the aggregation of TRQs from the detailed product level to CGE sectors or a disaggregation to product detail in CGE modeling. The aggregation approach is more common (e.g., Elbehri and Pearson, 2000; Berrettoni and Cicowiez, 2002; van der Mensbrugghe et al., 2003; van der Mensbrugghe, 2005) and depicts a TRQ switching regime at the sector level, even if not all related products fall under TRQs or TRQ structures differ across these products (Grant et al., 2009). However, marginal impacts at the aggregate level can vary dramatically, depending on the TRQ regime that is active at the detailed product level (Chepeliev et al., 2019, Golub et al., 2020). A few studies (e.g. Decreux and Ramos, 2007; Chepeliev et al., 2019; Golub et al., 2020; Jafari et al., 2021) have developed approaches that allow the treatment of TRQs at a desired level of bilateral trade resolution given the data availability.[4] Golub et al. (2020) have provided the most recent application, thereby presenting a framework (GTAP-HS-TRQ) that disaggregated larger parts of the CGE model to Harmonized System (HS) 6 detail, including all bilateral trade flows and domestic sales. By contrast, to reduce the data needed for such detail, Jafari et al. (2021) split variables related to *selected* bilateral trade flows to tariff line detail, which are subject to liberalization. This framework removes the aggregation bias and allows for substitution between narrowly defined products at the level of bilateral trade flows. Following their approach, we explicitly allow for TRQ regime shifts for each detailed product, which allows the provision of evidence on the potentially associated biases related to the previous approaches.[5]

To illustrate our approach, we consider the Canada–EU trade agreement (CETA) focusing on two politically sensitive sectors where TRQs are found in the agreement: dairy for Canada and some meat sectors for the EU. These two sectors are among the most protected ones worldwide[6] and provide typical examples of sensitive sectors in trade agreements protected by (newly) introduced TRQs.

The remainder of the study is presented as follows. Section 2 discusses the importance of modeling TRQs in FTAs, possible TRQ regimes, the different approaches to depict TRQ policies in the CGE models and their consequences on the analysis of trade impact, and the relevance of TRQs in the

[4] These approaches are based on nested constant elasticity of substitution (CES) and constant elasticity of transformation (CET) import demand and export supply equations. Chepeliev et al. (2019) and Jafari et al. (2021) have not directly introduced TRQs in their approach but both models suggest the related frameworks for explicit TRQ modeling. Decreux and Ramos (2007) implemented TRQs at HS6 level in the Mirage model.

[5] It is important to realize the circumstances under which the projected trade impacts, and consequently domestic consumption/production and welfare are over- or underestimated. For example, depending on the share of imports in domestic consumption, significant impacts will be observed on domestic sectoral output, household consumption, and welfare.

[6] In 2016, the average tariff, in chapter HS2 "02" (Meat) was 32.9% and 35.9% in HS2 "04" (Dairy), while the average agri-food sectors (chapters 01 to 24) was 16.2% and 4.1% when considering all products (source: MAcMap-HS6).

CETA agreement. Section 3 presents the proposed methodology that allows the implementation of TRQs explicitly and at different bilateral trade resolution. Section 4 details the software and baseline data. Section 5 specifies the scenarios, followed by Section 6 discussing the results. The final section concludes.

2. Literature

2.1. Importance of TRQs in FTAs

One of the achievements of the Uruguay Round Agreement on Agriculture (URAA) was the tariffication of several types of existing tariffs and nontariff barriers (NTBs) into one binding MFN tariff (Skully, 1999). In some cases, this process led to prohibitively high tariffs, and TRQs were implemented to provide some market access in such cases (Beckman and Arita, 2017). TRQs are a two-tier tariff scheme: a tariff charged on imports under a defined quota and an additional higher tariff charged such that the applied tariff becomes a step function of the import quantity. The higher tariff is generally equal to the MFN tariff for the World Trade Organization (WTO) members.

After the URAA, more than 1,400 individual TRQs for agri-food commodities alone have been introduced through the WTO, thereby reflecting high levels of protection (Beckman et al., 2021). As shown in Table A1, Norway (232 TRQs) imposes the most quotas in agri-food sectors, followed by the EU (117), Iceland (90), Columbia (67), and South Korea (67) (WTO, 2018). China trades more than 14 million metric tons (MMTs) under TRQs annually, followed by the EU (9 MMTs) and Japan (8 MMTs), jointly accounting for approximately half of the agri-food trade under TRQs (Beckman et al., 2021).

2.2. Economics of TRQs

The structure of the TRQ system, together with the import demand and supply conditions, determines the tariff applied to the imported product and its price. Panels a to c in Figure 1 illustrate different possible TRQ regimes. Across the panels, ES_0 and ID denote the initial import supply and demand functions for a given country that define its average cost–insurance–freight (c.i.f) price.[7] The presence of the TRQ shifts the import supply curve depending on the quota volume and two tariffs, namely, the In-Quota-Tariff Rates (IQTR) and the Out-Quota-Tariff Rates (OQTRs). The IQTR is frequently zero, and the OQTR is often equal to the MFN rate (Ingco, 1996; Diakosavvas, 2001; De Gorter and Kliauga, 2006). Assuming that the IQTR is zero, such that imports below the quota level are duty-free, the TRQ shifts ES_0 to ES_1.[8] Accordingly, the interaction of ID and ES_1 determines the tariff applied under the TRQ system (and therefore the related import price), which leads to the following regimes:

1. Underfill: Import demand does not meet the quota level, that is, the fill rate is less than 100%, as shown in panel a. The IQTR applies and import price is equal to the c.i.f. price times (1 + IQTR).
2. Binding quota: Import demand exactly meets the quota level as in panel b. In this case, the IQTR applies and the price for imported quantity is determined by the location of the ID curve and where it crosses the vertical part of ES_1.[9] The price paid by the importer is equal to the c.i.f. price if the rent is collected by the importer or equal to the c.i.f. price plus the

[7] Assuming that the c.i.f. price is not affected by import quantities does not change the analysis.

[8] The TRQ structure holds as long as the IQTR is smaller than the OQTR. We assume a zero IQTR for the sake of simplicity, as is often done in FTAs.

[9] See discussion in Skully (1999) and Decreux and Ramos (2007) for the implication of different methods of TRQ administration on the distribution of TRQs rent.

per unit rent if the rents accrue to exporters. In both cases, the price for the imported region by demanders is equal to the c.i.f. price plus the per unit rent.

3. Overfill: Import demand exceeds the quota limit, as shown in panel *c*. In this case, the OQTR applies, and the price for the imported origin is equal to the c.i.f. price plus the OQTR. The rent revenue is maximal and equal to the quota quantity times the difference between OQTR and IQTR.

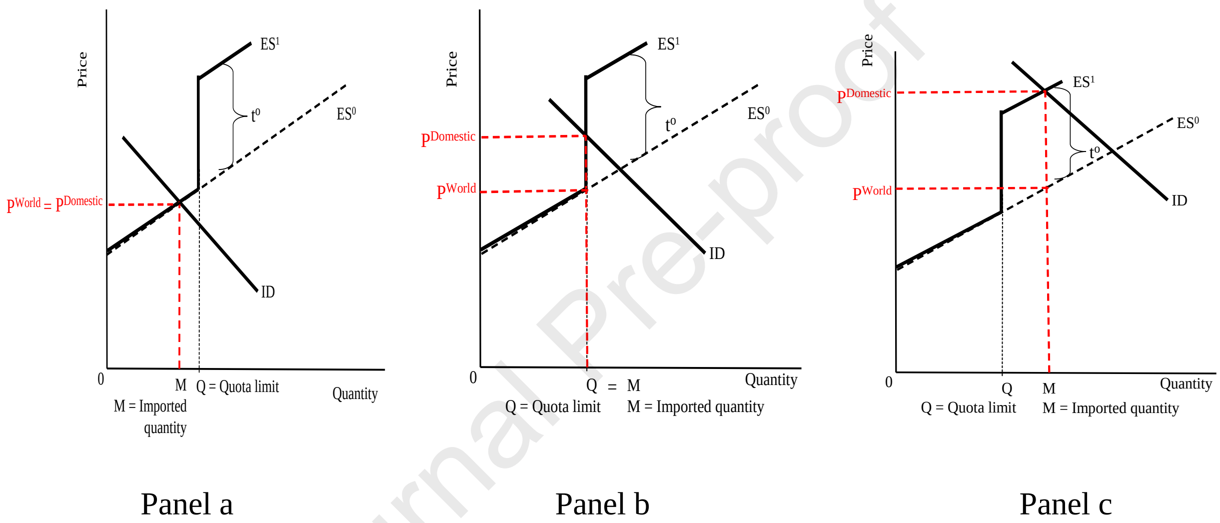


Figure 1. TRQ system under different import demand and supply conditions

Although the baseline imports and the IQTR and OQTR are known from the observed trade data, we cannot know ex-ante where import demand and the tariff rate under counterfactuals. In the case of a binding, but not overfilled quota, the per unit rent cannot be observed or easily derived, particularly if the imported and domestic products are not perfect substitutes. Only if one assumes that rents fully accrue to exporters, the usually observed c.i.f. price would comprise the rent, and the price for the imported origin would be known. In this case, however, it would be challenging to predict the c.i.f. price under future underfill because the observed free-on-board (f.o.b.) price is not equal to the marginal cost but comprises the rent. These problems led to a larger body of literature proposing different ways to handle TRQs and the related difficulty. The primary modeling issue is the nonequalities associated with the kinked structure of the shifted import supply curve. Common approaches that implicitly convert TRQs to AVEs calculate some weighted average of IQTR and OQTR or measure the AVEs of TRQs based on the marginal rate of protection, as discussed next.

2.3. Explicit versus implicit modeling TRQs in CGE

Converting TRQs into AVEs has become standard in the trade modeling literature, which Cipollina and Salvatici (2008) term the "natural" solution in CGE analysis. Perhaps the most widely used approach for converting TRQs into AVEs is the MAcMap-HS6 data set (Bouët et al., 2008; Guimbard et al., 2012), which computes the marginal protection (AVE) of a TRQ based on the IQTR, OQTR, the quota volume, and the observed imported quantities. The ratio on quantities (imported over authorized) provides the fill rate of a given TRQ. If this rate is smaller than 90%, underfill is assumed and the AVE is set equal to the IQTR.[10] For import quantities exceeding 98% of the quota volume, quota overfill is assumed and, accordingly, the AVE is set equal to the OQTR. For the intermediate case (90%–98% fill rate), a binding quota is assumed and MAcMap estimates the per unit rent as a simple average of the IQTR and OQTR.[11] Although these AVEs are useful for comparing protection levels and are straightforward to implement, they might create an endogeneity bias related to trade and tariffs (Anderson and Neary, 2005).

Given the different pieces of information that a TRQ entails, explicitly accounting for them in the CGE models has been a challenge for researchers (Horridge, 1993; Bach and Pearson, 1996;

[10] The IQTR and OQTR is often a specific or compound rate and thus itself might require a conversion in an AVE based on trade unit values.

[11] The intermediate case refers to the situation where there is uncertainty on whether quota is binding or not. Due to administrative or technical obstacles, quotas might be binding even if the imports are slightly lower than the quota.

Harrison and Pearson, 1996; Elbehri and Pearson, 2000; Berrettoni and Cicowiez, 2002). van der Mensbrugghe et al. (2005) extended this work using an MCP approach (Rutherford, 2001) to implement TRQs, which provide information on the tariff rate, import level, and quota rent to explicitly represent regime switching. This approach has become a standard in CGE modeling when TRQs are explicitly modeled (Beckman et al., 2017).[12]

2.4. Consequences of modeling of TRQs in CGE using MCP and MAcMap

The explicit representation of TRQs in the CGE models by using MCP reflects the detailed TRQ structure as shown in Figure 1. In this approach, the initial tariffs in panels a and c are calibrated exactly using the IQTR and OQTR, respectively, while in panel b the per unit rent as the initial tariff is typically taken –similar to MAcMap–as the arithmetic mean of the two tariffs. This approach can be interpreted as the assumption that the quota rent is equally distributed between the exporter and importer partners. When a policy shock is implemented, the location of the ID curve and, therefore, the TRQ regime can change from one panel to the other. The MCP approach tracks the new location of the ID curve, the new quota regime, and the final tariff rate.

The traditional AVE approach might project different percentage changes in tariffs compared with the MCP solution for several reasons. First, the initial tariffs in the model are calibrated differently in MAcMap than under an MCP solution if the initial fill rate is within [90–100]%. Considering Figure 1 (panel a), the initial tariff is zero if the fill rate is less than 90%, which is consistent with MCP. The initial tariff rate is $0.5t^0$ if the initial fill rate is between 90% and 98%, and t^0 if the initial fill rate is higher than 98%. If the fill rate is 100% (panel b) or higher (panel c), MAcMap

[12] Another approach is that introduced by Liapis and Britz (2001), based on a sigmoid function and equivalent to the MCP solution, but requires higher coding efforts. It allows using general-purpose non-linear solvers and makes the approximation of the nonlinearities transparent. In an MCP solution, such approximations are performed by the solver in the background and more flexibly handled compared to Liapis and Britz (2001).

still takes t^0 as an initial tariff rate. Second, under an AVE approach, the postshock location of the ID curve and thus the final fill rate must be determined before the actual model simulation, and this fill rate could be different from the one simulated under an MCP approach. The assumed final fill rates under the MAcMap approach are calculated as the observed trade quantity in the baseline over the new quota. In other words, fill rates are calculated based on the assumption of no change in the actual traded quantities. This assumption is likely to differ from the actual simulation results of the CGE model, thereby leading to potential inconsistencies with premodel assumptions and in differences between the results obtained using the AVE and explicit TRQ approach. Third, even if the assumed final fill rate is correctly identified, in cases where the final fill rate is within [90–100]%, the AVE rate under the MAcMap is different from that under the MCP approach; as for any fill rate less than 100%, the MCP approach will always use the IQTR as the relevant tariff; and for fill rates of 100%, it uses a tariff between the IQTR and OQTR.

As mentioned previously, MAcMap considers different initial and final tariff rates within the fill rate of [90–100]% primarily to reduce biases that might arise from projecting the wrong TRQ regime after a policy shock. Nonetheless, this approach does not remove the bias under many circumstances. In particular, quota expansions that allow ex-post fill rates higher than 90% decline to less than 90% assume the application of the IQTR (= underfill) ex-ante, and the CGE model might respond to the related tariff drop by expanding trade beyond the allowed quota, where a different marginal tariff would be applied. Therefore, the MAcMap approach tends to overestimate impacts. Moreover, MAcMap can easily lead to biased results if a policy leaves the TRQ-related instruments (i.e., quota level, IQTR, and OQTR) unchanged but changes the location of the import demand curve, such as by changing nontariff measures (NTMs), for example, an initial situation as in panel *a* (underfill) and a policy-induced upward shift in import demand, which leads to a

TRQ shift from panel *a* to panel *b* (binding quota) or *c* (overfill). The MAcMap approach will lead to an overestimation of trade impacts because it will continue to use the IQTR. Similarly, results are overestimated if panel *b* (binding quota) is the initial situation and import demand because of non-TRQ policy shifts to a regime as in panel *c*. There are also circumstances leading to the underestimation of the results. This is the case when the import demand curve, moves downward reflecting a shift from higher to lower tariff regimes because of a non-TRQ policy; for example, when policies increase competitiveness of importers.

2.5. Sectoral- versus product-level representation of TRQs

Another aspect related to the implementation of TRQs is the product detail considered in the analysis. TRQs often include some product levels ranging from HS4 to HS6 or even narrower definitions for which international trade statistics are not generally easily available. Databases dedicated to global CGE analysis offer fewer details such that either the model structure is expanded to reflect the variables related to bilateral trade (and potentially further transactions, e.g., domestic sales) at higher detail, such as at tariff line level (see, Chepeliev et al., 2019; Golub et al., 2020; Jafari et al., 2021), or TRQs defined at the product level are aggregated to the sectoral level of the CGE.

Lips and Rieder (2002) suggested two approaches to implement TRQs for individual tariff lines at a more aggregate level. The first and more common approach estimates AVEs from each TRQ, which are later aggregated to an average AVE (e.g., Agbahey et al., 2017). In this approach, the CGE model cannot consider regime switches or changes of the quota rent endogenously. In the second approach, a TRQ switching regime at the aggregate product level is introduced in the CGE model, with its quota volume equal to the sum of the individual TRQs and its IQTR and OQTR derived as trade-weighted averages. Cipollina and Salvatici (2008) considered this approach as an "atheoretic" approximation to an equivalence index. In particular, if the initial regimes of the individual TRQs differ, simulated changes in the aggregated TRQ regime are ambiguous (Bouët et al., 2005). Furthermore, the product aggregates may comprise tariff lines not subject to TRQs that will become subject to the aggregated TRQ regime. Both approaches face potential aggregation bias. Jafari et al. (2021) found in their CETA analysis that the premodel aggregation of AVEs across tariff lines results in higher trade and welfare impact.

2.6. CETA agreement and status of trade between the EU and Canada

To further clarify the complex analysis of TRQ policies, we present the status of trade and changes in TRQs due to CETA, which is chosen as the example for numerical illustration. CETA is a free trade agreement between Canada and the EU, which is provisionally applied since autumn 2017.[13] When fully phased in, it will remove tariffs for 98% of all tariff lines between the two regions. For agricultural products, 94% of the EU tariff lines and 91% for Canada will be duty-free, whereas for tariff lines with existing TRQs, the IQTR or OQTR might change and/or quotas might be expanded.

Table 1 shows the bilateral import values of Canada and EU, along with shares in total imports. Reflecting the size of the economies, 0.8% of EU imports stem from Canada, as opposed to 15.5% of Canadian imports from the EU. Bilateral import shares of agri-food products are slightly lower, with 0.7% and 12.1%, respectively. However, the share of EU imports from Canada is substantially higher in some cases, such as for wheat (10.6%), oilseeds (3.0%), and other cereals (2.8%). For beverages and tobacco (43.1%), other animal products (35.9%), dairy products (29.6%), and wool products (28.3%), the EU's share in Canadian imports is quite important.

[13] Canada, all EU Member countries, and the European parliament have approved the agreement, but the ratification of some EU Member states is pending along with a positive opinion by the European Court of Justice.

Table 1 also shows the initial AVEs of tariffs between the EU and Canada and their percentage reductions because of CETA (calculated with MAcMap) at the agri-food sectoral level of GTAP database for agri-food. Manufacturing and extraction sectors are summarized because they are fully liberalized, whereas no trade in services and related protection is currently covered by the data.

Table 1. The EU–Canada trade and tariffs

	EU import				Canada Import			
	Import value (Mil USD)	Share from total import (%)	initial import tax (%)	Reduction in import tariff due to CETA (%)	Import value (Mil USD)	Share from total import (%)	initial import tax (%)	Reduction in import tariff due to CETA (%)
All sectors	54.98	0.80	0.9		86.61	15.51	1.0	
Agri-food	3.20	0.65	6.4		4.46	12.14	1.7	
MEAT*	0.05	0.08	18.9	36.5	0.11	3.22	0.8	22.5
Wheat (WHT)	0.81	10.59	5.0	100	0.01	25.64	0.5	100
Cereal grains nec (GRO)	0.28	2.79	0.1	100	0.02	3.93	0.0	100
Vegetables, fruit, nuts (V_F)	0.29	0.46	0.5	100	0.15	2.29	1.6	100
Oil seeds (OSD)	0.41	2.98	0.0	100	0.01	1.11	0.0	100
Plant-based fibers (PBF)	0.00	0.00	1.0	100	0.00	-	0.0	100
Crops nec (OCR)	0.04	0.12	2.2	100	0.09	5.64	2.0	100
Cattle, sheep, goats, horses (CTL)	0.03	0.56	0.2	100	0.02	20.72	0.0	100

Animal products nec (OAP)	0.16	1.09	0.6	99.9	0.37	35.86	0.0	95
Vegetable oils and fats (VOL)	0.04	0.10	2.8	100	0.18	12.23	1.0	99.9
Dairy products (MIL)	0.02	0.05	38.7	100	0.18	29.57	1.7	6
Sugar (SGR)	0.06	0.70	4.2	100	0.01	1.15	2.8	100
Food products nec (OFD)	0.93	0.61	16.1	99	1.26	8.97	4.4	74
Beverages and tobacco products (B_T)	0.08	0.14	2.2	100	2.03	43.05	0.5	99.9
Extraction	5.02	0.90	0.1	100	0.22	1.00	0.1	100
Manufacturing	25.43	0.60	1.0	100	45.56	11.32	1.6	100
Services	21.33	1.35		-	36.37	40.65	0.0	-

Source. GTAP database (GTAP 10, 2014 reference year) for initial trade volume and import tax rates; Jafari et al. (2021) for percentage change in import tax rate based on MAcMap-HS6 reference group method that considers sensitive products for which tariffs are not reduced or reduced only partially

Note: * Meat refers to the aggregate of Meat: cattle, sheep, goats, horse (CMT) and Meat products nec (OMT)

As shown in Table 1, the dairy sector with an AVE of 38.7% and meat with an AVE of 18.9% are the most protected EU sectors before the implementation of CETA, as shown by the low import shares from Canada. The AVEs for Canada are substantially lower with 1.7% in case of dairy and 0.8% in case of meat, although they are partially protected by TRQs, which again underlines the challenges of converting TRQ regimes into AVEs. The negotiations for meat and dairy sectors are often challenging in FTAs. For example, in the Trans-Pacific Partnership, the dairy sector was a primary sticking point in negotiations for Canada (Schott et al. 2016), similar to the meat sector for the EU when negotiating the Transatlantic Trade and Investment Partnership (Jafari et al., 2019).

Next, we summarize the status of the EU–Canada bilateral protection of cheese and meat before and after CETA based on the legal text of the agreement (European Union, 2017). Under CETA, EU cheese exports will remain subject to a TRQ with a prohibitive OQTR; however, its quota will be increased from 13,500 tons to 31,972 tons. The EU protects its beef sector with TRQs featuring prohibitive MFN rates, with two quotas relevant for Canada before CETA: the High-Quality-Beef (HQB)-TRQ[14] with 4,162 tons and the Fresh-beef-TRQ with 1,150 tons.[15] For the HQB-TRQ, the IQTR is lowered from 20% to 0% at unchanged quantities, whereas the Fresh-beef-TRQ is expanded by nearly a factor of 30, to 31,164 tons. Additionally, the FTA introduces two new TRQs: the Frozen-beef-TRQ with 15,000 tons and the Bison-TRQ[16] with 3,000 tons. All TRQs face a 0% IQTR. Accordingly, the total quota related to beef imports from Canada to the EU has increased around 10-fold in CETA, approximately from 5,300 tons to 54,000 tons, whereas out-of-quota and over-quota trade will likely remain of minor relevance given the high OQTRs and out-of-quota MFN rates.

The literature review of papers on CETA in Jafari et al. (2021) has shown that older papers estimate substantially higher impacts because they did not yet consider exceptions for sensitive products and tended to have lower sectoral and regional detail. This underlines the need for more detail in CGE studies, particularly to consider exemptions for sensitive products. Jafari et al. (2021) have concluded that models should be "extended to trade policy instruments with variable *ad-valorem*

[14] The High-Quality Beef Quota (HQB), otherwise known as "Hilton," beef refers to the special type of beef cuts obtained from exclusively pasture-grazed animals of certain age, weight, etc.

[15] 11,500 tons of the EU bovine meat quota is shared between the United States and Canada. We assume that 10% of this amount is allocated to Canada because it represents 10% of the total export of beef from Canada and United States to the EU.

[16] As part of the EU commitment to the WTO, the EU also grants a 45,000-tons grain-fed beef quota that can be accessed by Australia, the United States, Canada, New Zealand, Uruguay, and Argentina. The quota is not affected by CETA.

tariff rates (e.g. TRQ, specific tariffs, composite tariffs), modelling changes in AVEs endogenously."

3. Methodology

This study uses the modular platform for CGE modeling "CGEBox" (Britz and van der Mensbrugghe, 2018). It takes the standard GTAP model (Corong et al., 2017, van der Mensbrugghe, 2018) as its core, expanding it optionally by variants dealing with factor supply; production; demand; and a range of options to depict trade (Jafari and Britz, 2018), including a disaggregation of bilateral trade to a more fine-grained resolution, as in Jafari et al. (2021). CGEBox, accompanied by an aggregation and disaggregation facility (Britz 2021), is used to transform the GTAP Data Base into the desired dataset for simulation purposes. It comprises an algorithm to filter out small data entries from the global CGE database and later rebalance it to improve numerical stability when solving the CGE model (see Britz and van der Mensbrugghe, 2016).

Next, we discuss the extension of this framework to explicitly capture TRQs.

3.1. Representation of TRQs in the tariff line module based on MCP

Jafari et al. (2021) have further categorized commodities relating to selected bilateral trade, see extensions in Figures 2 and 3 [for further detail see Jafari et al. (2021)], thereby leaving domestic supply and demand at the sectoral detail of the CGE database. We extend this module for an explicit MCP representation of bilateral TRQs, thereby yielding a fully consistent aggregation from the tariff line to the product level and to the sectoral level.

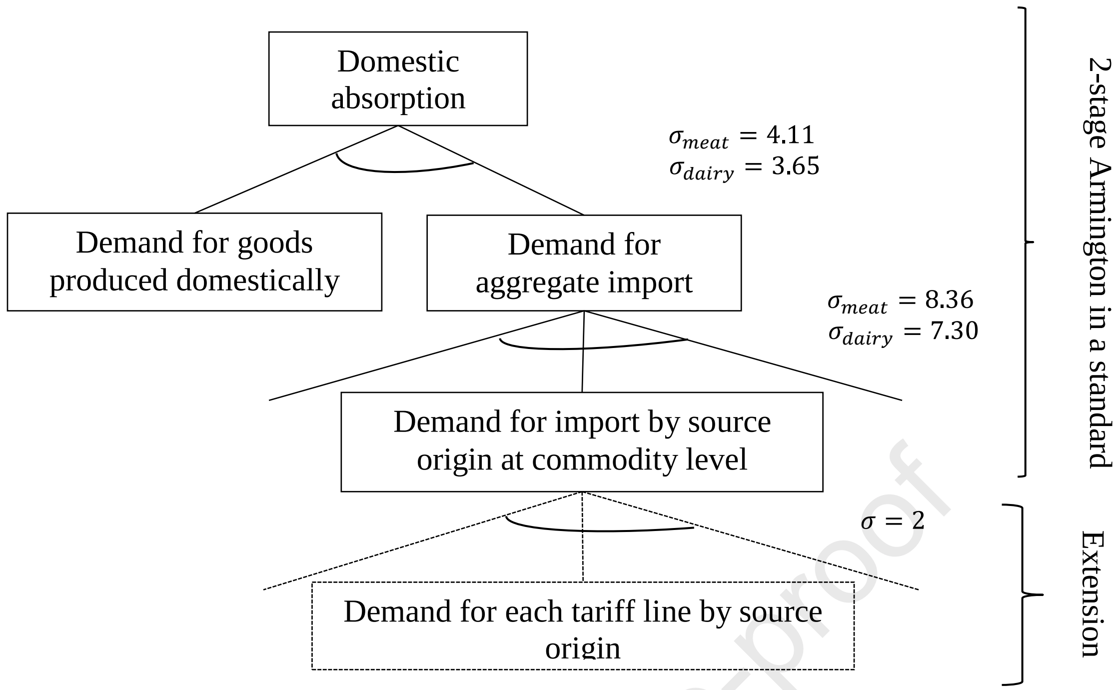


Figure 2. Nested Armington demand

Note: σ refers to substitution elasticities in the CES functions. The substitution elasticities for the two higher nests are from the GTAP Data Base as used in the standard GTAP model (van der Mensbrugghe, 2018) and for the lower nest from Jafari et al. (2021). **Source**: Jafari et al. (2021)

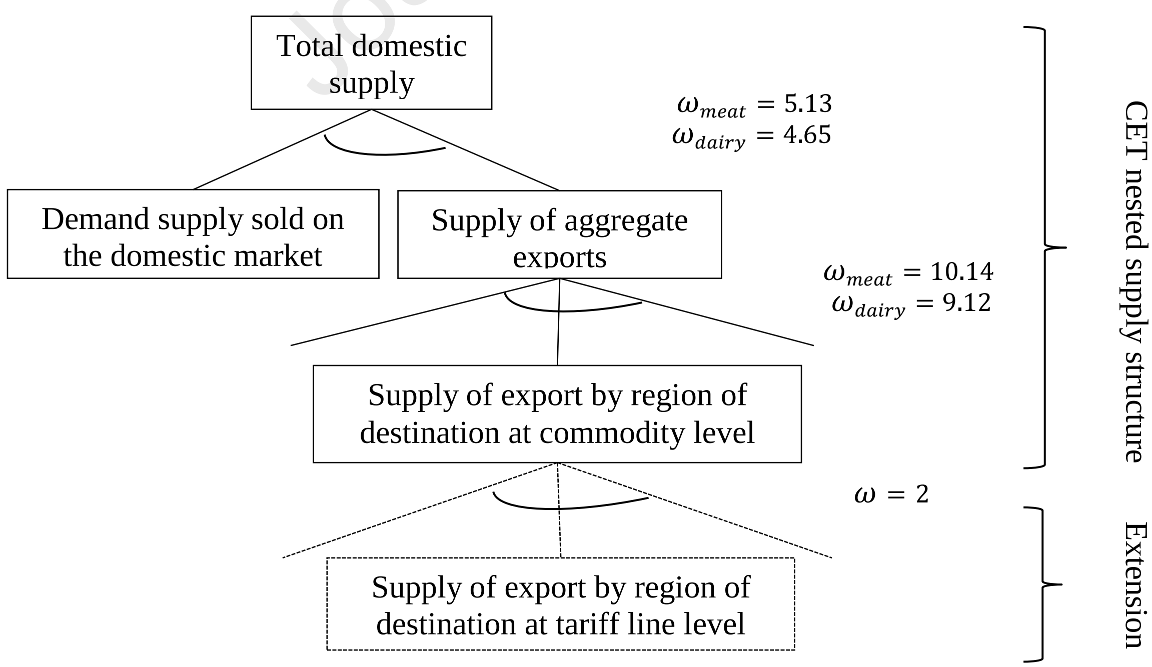


Figure 3. Nested CET supply

Note: ω refers to transformation elasticities in the CET functions. The transformation elasticities for the two higher nests are derived based on the substitution from the GTAP Data Base, where CET elasticities are higher than CES elasticities by factor 1.25 (Britz and van der Mensbrugghe, 2018) and for the lower from Jafari et al. (2021). **Source:** Jafari et al. (2021)

The bilateral import tax defined at the tariff line level becomes endogenous under TRQs. Therefore, we use the MCP approach to allow for tariff regime shifts based on complementary slackness conditions similar to that found in the LINKAGE model (van der Mensbrugghe, 2005), the GLOBE model (Burrell et al., 2011), Himics and Britz (2013), and Himics et al. (2020).

$$Quota - I^{iq} \geq 0 \perp t^{s} \geq 0, \tag{1}$$

$$t^{oq} - t^{iq} \geq t^{s} \perp I^{oq} \geq 0, \tag{2}$$

$$\tau^{m} = t^{iq} + t^{s}, \tag{3}$$

$$\mathrm{I} = I^{oq} + t^{iq}. \tag{4}$$

Equation (1) represents the regime switch between IQTR to OQTR regimes under TRQs. If in-quota imports, I^{iq}, reach or exceed the quota level, $Quota$, then the unit quota rent, t^{s} (the shadow tariff that defines the quota rent per unit of imports), becomes nonzero, thereby representing an OQTR regime. Equation (2) defines bounds for the shadow tariff that should be equal to the difference of IQTRs and OQTRs (t^{iq} and t^{oq}, respectively) if out-of-quota imports I^{oq} occur. Equation (3) defines the endogenously determined applied tariff rates τ^{m} based on the in-quota and shadow rates, and finally equation (4) is the import balance defining total imports I. This system of equations is defined for all tariff lines that are subject to bilateral TRQs.[17]

4. Data

We use the latest GTAP Data Base (GTAP 10, with 2014 as reference year) as the benchmark, and keep its full 65 sector resolution, except for the two meat sectors, that is, ruminant meat (CMT) and other meat (OMT), which are aggregated into a single MEAT sector as different meat TRQs in CETA relate jointly to CMT and OMT. This aggregated MEAT sector and the dairy sector (MIL) are disaggregated to high detail on the EU–Canada trade link. The model considers three regions: the EU, Canada, and rest of the world.

Trade, Tariffs, and TRQs data

To break down bilateral trade data at different resolutions, a part of bilateral trade data relating to MEAT and MIL (products that are subjected to TRQs) are disaggregated to the 8-digit-level tariff-line level detail[18] based on information from COMTRADE for Canada and from COMEXT for the EU. We do not disaggregate the parts of MEAT and MIL that are not subjected to TRQs. The information for the product and tariff lines affected by TRQs are obtained from the official WTO MFN tariffs for the benchmark and from the CETA agreement text (European Union, 2017) for the counterfactual, including changes in IQTRs, OQTRs, and TRQ volumes. The AVEs of tariffs for products not affected by TRQs are obtained from the MAcMap-HS6 dataset (2014).

[17] If the tariff lines are subjected to non-bilateral TRQs, one could follow the common approach in the literature to exogenously distribute a given tariff line quota to different countries based on a certain exogenous share. Alternatively, the quota allocation shares across countries can be endogenously determined depending on the mechanism of quota allocation between countries.

[18] HS8 codes are not harmonized globally such that, for instance, MAcMap and similar global data sets are available at the HS6 level, only. To consider more detail, we use here statistics provided by the EU and Canada as importers using their specific HS8 definitions (for detail, see Table A2).

The definition in the CETA text for trade that falls under each TRQ exceeds the HS8 detail for which trade data are available. For example, for the MEAT sector, no trade information is readily accessible to distinguish the trade of fresh and frozen beef, bison, and HQB beef. At the 8-digit tariff line, the Fresh-beef-TRQ and Frozen-beef-TRQs are mutually exclusive across tariff lines; however, trade under some tariff lines could be placed under each of three TRQs: Bison-TRQ, HQB-TRQ, and Fresh/Frozen-TRQ (see Table A5, for the complexity of TRQs in the meat sector). The fresh and frozen meat TRQs are mutually exclusive because the HS8 tariff line definitions distinguish this clearly. However, whether beef meat stems from bison cannot be determined from the HS8 classification, such that trade under any of the tariff line could be allocated to the Bison-TRQ. Similarly, some frozen or fresh meat tariff lines might be imported under the HQB-TRQ depending on further product properties not reported in the HS8 classification but checked by custom authorities. Consequently, there are multiple tariff lines that could be mapped to three TRQs. To implement the TRQs in the CGE, we distribute the quantity of TRQs to the relevant tariff lines based on the observed import value and/or aggregate TRQs into a single MEAT_AggTRQ. The latter seems defensible (see Table 2) because the Bison and HQB TRQs account for a small share of the summed up quota; their OQTR are always MFN rates, and only the IQTR of HQB-TRQ is different from other TRQs. Accordingly, we do not expect significant bias, if any, associated with this aggregation approach.

Table 2. TRQs of EU cheese imports into Canada and Canadian meat imports into the EU (tons)

	Baseline	Expansion in CETA agreement	Post- CETA
Cheese TRQ	13472	18500	31972

Meat			
Fresh-TRQ	4162	35002	39164
Frozen-TRQ	0	15000	15000
HQB-TRQ	1150	0	1150
Bison-TRQ	0	3000	3000
MEAT-AggTRQs	5312	53002	58314

Source: Authors' compilation based on CETA text.

5. Scenario specifications

We consider four scenarios differentiated along two dimensions for our comparative static analysis. The first dimension is the level of the product detail considered, thereby keeping the original GTAP sectors or disaggregating to HS8. The second dimension is whether TRQs are modeled explicitly or presented implicitly as AVEs based on the MAcMap approach (see Table 3).

Table 3. Scenario layout

	Level of bilateral Trade Resolution		**TRQ Modeling**	
Scenarios	Sector	Tariff Line	Explicit	Implicit
TRQ_Sec	✓		✓	
TRQ_TL		✓	✓	

AVE_Sec	✓		✓
AVE_TL		✓	✓

*Tariff line resolution is considered only for products affected by TRQ, that is, Cheese and Beef. In the TRQ_TL scenario, the parts of meat and beef sector unaffected by TRQs are modeled as that in AVE_TL. The implementation of TRQs for all other commodity sectors other than Cheese and Beef is consistent with AVE_Sec.

Tables 4 and 5 show the details on the TRQs in the dairy and MEAT sectors, respectively. The initial and post-CETA quotas for each TRQ are distributed across the tariff lines based on the observed trade share of each tariff line on the total import value of each aggregated sector defined in scenario 3.[19] The post-CETA column shows, in addition to the potential changes in the IQTR and quota, the AVE at unchanged trade quantities, as calculated by MAcMap, assuming the same fill rate for all HS8 lines mapped to a TRQ. For the scenarios defined at the aggregated level, the lines at the bottom report the relevant information.

[19] We also introduce a framework (see Appendix B) that endogenously allocates quotas across tariff lines, where a virtual export distributor allocates quotas endogenously to different tariff lines to maximize its profit. This approach, however, requires the marginal willingness to pay at the tariff line level by the export partner that is unfortunately not easily obtainable. Future studies might use the introduced approach depending on data availability.

Table 4. Trade and TRQs of Canada Import from the EU of Dairy Products

Import				Pre-CETA					Post-CETA			
Product level	HS8	Value	Quantity	IQTR (%)	OQTR (%)	Quota (ton)	Fill rate	AVEs (%)	IQTR (%)	OQTR (%)	Quota (ton)	AVEs (%)
	04061020	524751	67.7	0.71	245.5	66.50	1.01	245.5	0	245.5	157.8	0
	04062012	1728	0.25	0.48	245.5	0.25	1.01	245.5	0	245.5	0.6	0
	04062092	597493	44.9	0.56	245.5	44.10	1.01	245.5	0	245.5	104.7	0
	04063020	4085390	449.0	0.58	245.5	441.02	1.01	245.5	0	245.5	1046.6	0
	04064020	12598051	1020.0	0.36	245.5	1001.86	1.01	245.5	0	245.5	2377.6	0
	04069012	9918714	881.3	0.46	245.5	865.63	1.01	245.5	0	245.5	2054.3	0
	04069022	2815856	279.7	0.54	245.5	274.73	1.01	245.5	0	245.5	652.0	0
	04069032	11855967	1009.7	0.54	245.5	991.74	1.01	245.5	0	245.5	2353.6	0
Cheese	04069042	35850920	3150.0	0.54	245.5	3093.98	1.01	245.5	0	245.5	7342.7	0
	04069052	1327994	140.9	0.54	245.5	138.39	1.01	245.5	0	245.5	328.4	0
	04069062	1935844	191.46	0.54	245.5	188.06	1.01	245.5	0	245.5	446.3	0
	04069072	2536108	292.8	0.54	245.5	287.59	1.01	245.5	0	245.5	682.5	0
	04069082	72749	5.4	0.54	245.5	5.30	1.01	245.5	0	245.5	12.6	0
	04069092	1485025	154.4	0.54	245.5	151.65	1.01	245.5	0	245.5	359.9	0
	04069094	39980733	3053	0.54	245.5	2998.71	1.01	245.5	0	245.5	7116.6	0
	04069096	4501486	407.9	0.54	245.5	400.65	1.01	245.5	0	245.5	950.8	0

	04069099	27423520	2567.5	0.54	245.5	2521.84	1.01	245.5	0	245.5	5984.9	0
	Aggregate cheese	157512329	13716	0.52	245.5	13472	1.01	245.5	0	245.5	31972	0
Non-cheese		5533851	1550					16.94				8.86
MIL		163046180	15198	1.08	237.7	13472	1.12	237.7	0.3	237.5	31972	0.3

Note: See Table A3 for a description of the 8-digit-level commodities.

Table 5. Trade and TRQs of the EU Import from Canada of Meat Products

		Import		Pre-CETA					Post-CETA			
Product level	HS8	Value	Quantity	IQTR (%)	OQTR (%)	Quota (ton)	Fill rate	AVE (%)	IQTR (%)	OQTR (%)	Quota (ton)	AVE (%)
	02011000	0	0	20	60	0		20	0	60	0	0
	02012020	0	0	20	57	0		20	0	57	0	0
	02012030	0	0	20	48	0		20	0	48	0	0
	02012050	0	0	20	66	0		20	0	66	0	0
	02012090	136199	5.9	20	79	57.26	0.10	20	0	79	489	0
	02013000	6692130	486.7	20	67	4723.74	0.10	20	0	67	40333	0
	02021000	0	0	20	67	0		20	0	67	0	0
	02022010	0	0	20	51	0		20	0	51	0	0
	02022030	0	0	20	43	0		20	0	43	0	0
	02022050	0	0	20	61	0		20	0	61	0	0
	02022090	0	0	20	70	0		20	0	70	0	0
	02023010	168909	11.6	20	71	59.46	0.16	20	0	71	1957	0
	02023050	0	0	20	71	0		20	0	71	0	0
	02023090	1099552	92	20	92	471.54	0.20	20	0	92	15523	0
	02061095	0	0	20	63	0		20	0	63	0	0
Beef	02062991	0	0	20	144	0		20	0	144	0	0
	02102010	0	0	30	30	0		30	0	30	0	0

	02102090	0	0	33	33	0		33	0	33	0	0
	02109951	0	0	114	114	0		114	0	114	0	0
	02109959	0	0	13	13	0		13	0	13	0	0
	Aggregate Beef	8,096,790	597	20	70.6	5312	0.11	20	0	70.6	58314	0
Non-Beef		22,058,730	4422					5.76				0.61
MEAT		30,155,520	5019	9.80	23.17	5312	0.94	16.5	0.45	19.4	58314	0.45

Note: See Table A3 for the definition of 8-digit level commodities. Furthermore, note that the European Union’s import of pork from Canada is subject to an import TRQ. The existing WTO quota is 4,625 tons and CETA adds 75,000 tons to the initial amount. In this study, we only consider the AVEs of the TRQs for pork in the “Non-beef” sector for two primary reasons. First, as of 2019, the EU import of pork was only 1,000 tons, which is far away from the quota limits, and its modeling through implicit or explicit TRQ modeling does not make any difference. This is similar to the observed information for the beef, and we have chosen only one sector to illustrate the consequences of different ways of modeling TRQs.

6. Simulation results

Impacts of TRQ_TL and its comparison with AVE_TL

We first discuss the results from the most refined scenario combining tariff line detail with the explicit TRQ presentation. Using this approach, trade between Canada and the EU is simulated to increase by approximately 3% (see Figure 5). The primary drivers of increased Canadian exports to the EU are increased agri-food (20%) and manufacturing (4%) trade, whereas changes in the EU exports to Canada are primarily because of higher manufacturing (6%) and agri-food (3%) trade. This is consistent with welfare gains by 10.6 USD per capita for Canada and by 1 USD per capita for the EU. Higher gains for Canada per capita reflect improved access to a considerably larger market, whereas in absolute terms, the welfare gains of both partners are more comparable. The rest of the world is basically unaffected by a change of −0.01 USD per capita.

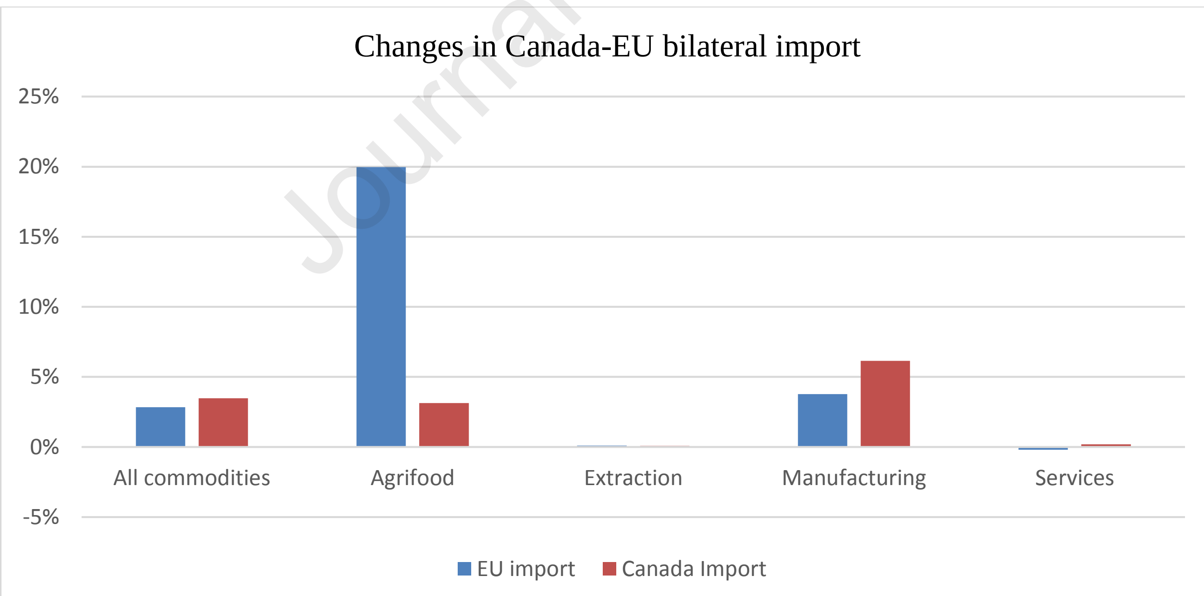


Figure 5. Trade impact of CETA under TRQ_TL

Table 6 presents the changes for agri-food sectors. Results indicate that Canada will increase its imports from the EU in all sectors, the largest increase being in dairy products (+8.2%), thereby reflecting the increase in the cheese TRQ, crops nec (+7.4%), vegetables and fruits (+7.2%), and sugar (+6.1%), in the latter cases primarily because their initial tariffs are relatively higher than that of other sectors and reduced by 100% (see Table 1). The EU imports of MEAT from Canada are projected to increase by 130%, thereby reflecting the TRQ expansions, followed by other food processing (38.7%) and wheat (24.8%) primarily because their initial tariffs are relatively higher than that of other sectors but reduced by almost 100% (see Table 1).

Table 6. The impacts of TRQ_TL on agri-food products

	EU's imports from Canada		Canada's imports from the EU	
	Baseline (Mil USD)	% change	Baseline (Mil USD)	% change
Agri-food	3.20	19.98	4.46	3.14
MEAT*	0.05	130.15	0.11	0.37
Wheat (WHT)	0.81	24.77	0.01	3.85
Cereal grains nec (GRO)	0.28	−0.05	0.02	0.47
Vegetables, fruit, nuts (V_F)	0.29	0.56	0.15	3.68
Oil seeds (OSD)	0.41	−0.45	0.01	0.17
Crops nec (OCR)	0.04	7.67	0.09	7.36
Cattle, sheep, goats, horses (CTL)	0.03	0.14	0.02	0.32
Animal products nec (OAP)	0.16	0.77	0.37	0.40
Vegetable oils and fats (VOL)	0.04	10.66	0.18	3.75
Dairy products (MIL)	0.02	−0.32	0.18	8.17
Sugar (SGR)	0.06	12.89	0.01	6.15
Food products nec (OFD)	0.93	38.68	1.26	7.23

Beverages and tobacco products (B_T)	0.08	2.68	2.03	0.61

Source. Simulation results.

* Meat refers to the aggregate of meat: cattle, sheep, goats, horse (CMT) and Meat products nec (OMT)

Further, we describe the changes in the two sectors subject to TRQs: Canadian meat exports to the EU and EU dairy exports to Canada. As presented in Figure 6, significant impacts are seen in the MEAT sector, with EU beef imports from Canada increasing by 168.2% and other meat by 113.6%. Canadian imports from the EU increase by 8% compared to the baseline. For the dairy sector, the EU exports of cheese to Canada increase by 8.2% and of the non-cheese sector by 6.4%.[20] Where imports are subjected to TRQs; that is, for Canadian cheese and EU beef imports, the initial import tariffs across tariff lines are all equal (reflecting the pre-CETA IQTR in the beef sector and the pre-CETA OQTR in the cheese sector) and are all reduced to zero. Therefore, no significant differences in bilateral import impact are seen across tariff lines.

[20]The aggregate Canadian tariff on cheese imported from the EU as reported in the GTAP 10 database is 1.7% (Table 1), far below the tariffs obtained from the MacMap database. In our database, this aggregated 1.7% tariff is split across different tariff lines, based on the tariff rates reported in Table 4. Therefore, small trade impacts are observed. The large differences between the tariffs found in the GTAP and MacMap databases mostly reflect that different fill rates are assumed at the benchmark. The GTAP database assumes an underfill such that the resulting tariff is an average of IQTRs, whereas the MacMap approach data assumes filled quotas and, thus, reports the QQTRs as initial tariffs.

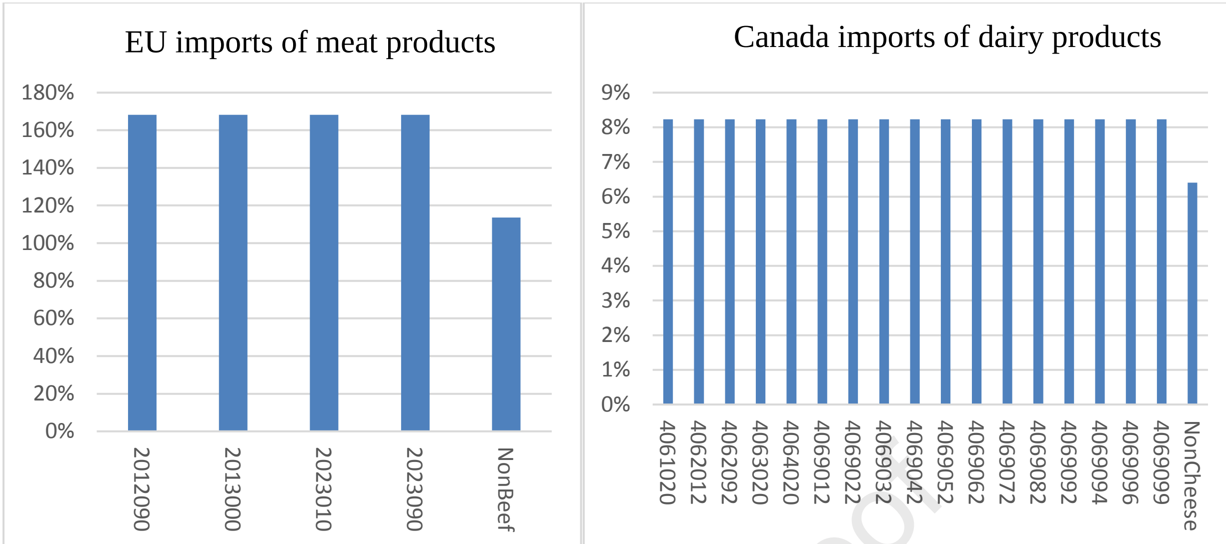
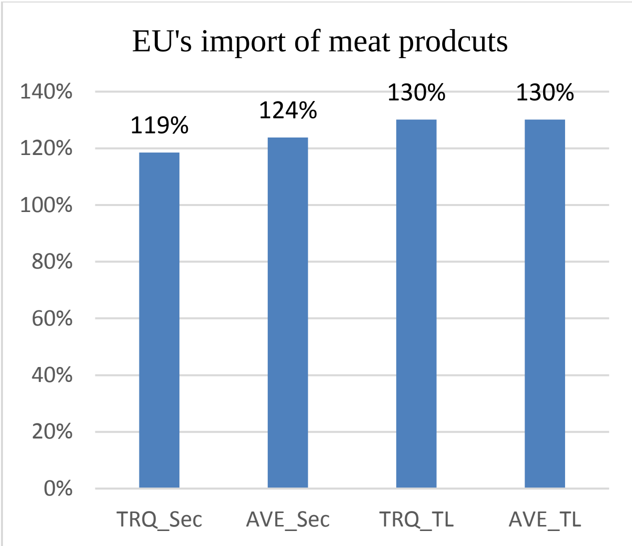


Figure 6. Changes in EU–Canada bilateral imports at the tariff line level, TRQ_TL

How do these results change when the level of details changes or TRQs are only considered implicitly? When considering product detail in the model, the MAcMap approach and the explicit TRQ representation yield the same result (Figure 7) because the tariff lines in the Cheese and Beef sectors have the same initial tariffs, which are subject to 100% reduction. In the meat sector, the quota is underfilled ex-post and in the simulation, and the IQTRs is reduced to zero. In the cheese sector, the quota is overfilled ex-post but underfilled in the simulation. Accordingly, the MCP mechanism will choose a zero IQTR as the relevant tariff for both sectors in the simulation that is equal to the AVE chosen by MAcMap because of significant underfill ex-post (fill rate <90%).



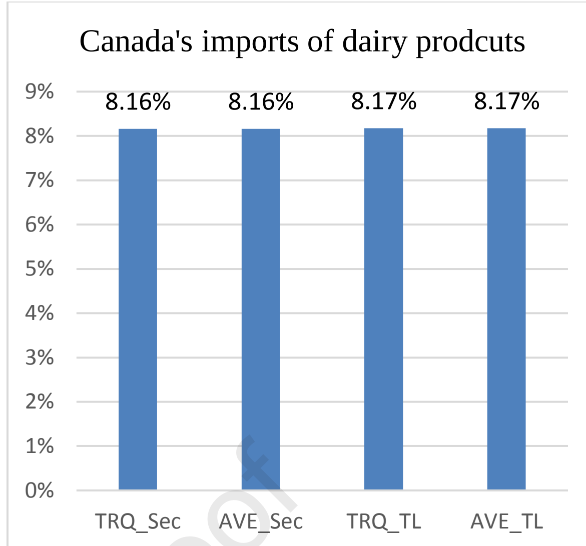


Figure 7. Changes in EU–Canada bilateral import across different scenarios

Impacts of TRQ_ Sec and AVE_ Sec and its comparison with _TL scenarios

What happens if shocks are implemented following the mainstream approach, that is, maintaining the original sector resolution? This implies implementing shocks (TRQ_Sec and AVE_Sec) on an aggregate sector where some parts are subjected to TRQs and others not, thereby running the risk of answering policy questions that are wrongly implemented or are ill posed. (Flores, 2008). Moreover, implementing the shock at the aggregate sector ignores the substitution possibilities between detailed products.

As shown in Figure 7, both the implicit and explicit implementation of TRQs in the aggregated case result in lower projected import changes of 119% and 124% compared with the detailed analysis, where 130% were found both in the TRQ_TL and AVE_TL scenarios. This aggregation bias might result from applying shocks to an aggregate where some tariff lines are not subject to TRQs and from ignoring substitution across detailed commodities. For the former effect, aggregating TRQs and normal tariffs dampens the shock and, therefore, underestimates the trade impacts. On the latter effect, the aggregation bias increases if higher substitution possibilities across the detailed products are assumed. Figure 8 compares different parameterizations of the detailed model against the aggregate solutions TRQ_Sec and the AVE_Sec. First, the bars labeled with _TL_2 and _TL_5 show that higher substitution elasticities increase simulated trade impacts compared with the standard pre-model aggregation case which implicitly assumes a substitution elasticity of zero.[21] If transformation and substitution elasticities across detailed products are set to zero (_TL_0), results under the detailed representation tend to be closer to working at the aggregate product level. Differences in these cases to aggregate scenarios (TRQ_Sec and AVE_Sec) stem from aggregating the trade subject to protection and the trade not subject to protection.

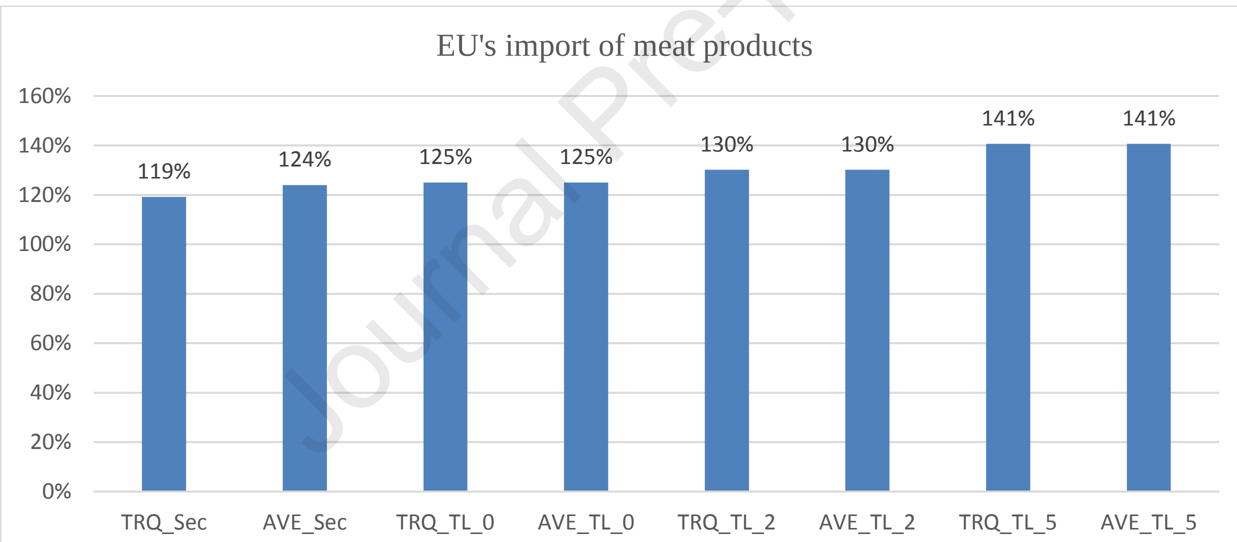


Figure 8: Sensitivity analysis on the CES and CET substitution elasticities

Moreover, the implicit and explicit treatments of TRQs at the aggregate sector estimate different trade impacts primarily because the two approaches project different percentage reductions in tariffs. For Canadian exports of MEAT to the EU (Table 5), beef products are subjected to TRQs

[21] A zero elasticity (lower bound for our sensitivity analysis) corresponds to the standard (fix) trade weighted tariff aggregator, which is implicitly used when the aggregation is performed pre-model.

and account for 26% of the import value; the remaining 74% of non-beef products use ordinary tariffs. Tariffs on beef products decrease from 20% (the initial IQTR) to 0% (the final IQTR), whereas non-beef tariffs decrease from 5.76% to 0.61%. If an aggregate TRQ is used in the model, its initial fill rate amounts to 94% (Table 5, the final row), such that under explicit and implicit representations of TRQs, the model is benchmarked against different initial tariffs, which is the opposite of the true disaggregated situation where the model is always calibrated against the IQTR. When using an aggregated meat sector, the related aggregated tariff reduces from 9.8% to 0.45% with an explicit TRQ mechanism, instead from 16.5% to 0.45% under the implicit treatment with AVEs (Table 5, the last row). Accordingly, higher trade impacts are found for the implicit approach. For example, in the MEAT sector, the trade impacts under the implicit and explicit treatments are 124% and 119%, respectively (Figure 7).

The estimated changes in the MIL sector (Figure 7) are only slightly lower when aggregated sectors are considered (TRQ_Sec and AVE_Sec) compared with outcomes by using product-level detail in the model (TRQ_TL and AVE_TL). One reason is that in the MIL sector, 98.7% of the import value from the EU into Canada stems from cheese products subject to TRQs (Table 4,); only a small remainder faces ordinary tariffs so that the aggregation bias becomes almost zero. Another reason is that because the tariff on all trade subjected to TRQs are reduced by 100%, considering substitution across commodities can be disregarded. In the MAcMap approach, the tariff on cheese decreases from 245.5% (i.e., initial OQTR) to 0% (final IQTR), whereas non-cheese tariffs decrease from 16.94% to 8.86%. When an aggregate TRQ is constructed, the resulting fill rate is 112%, such that the model is calibrated against the OQTR. Accordingly, both the explicit or implicit TRQs reduce the tariff from 237.7% to 0.3%.

Overall, the trade impact in TRQ_Sec and AVE_Sec are lower than that in other TRQ_TL and AVE_ TL scenarios (as evident in the MEAT sector); the potential bias associated with TRQ_ and AVE_ is found only if the original sector resolution of GTAP is maintained. In this case, the model is calibrated to different tariff rates compared with the detailed presentation, and substitution possibilities between detailed products are not considered.

Importance of properly capturing TRQs under different assumptions ex-post and ex-ante

Thus far, we have shown the importance of explicit and implicit treatments of AVEs by comparing TRQ_Sec and AVE_Sec. The two approaches have shown no differences at the tariff line level for the specific data and policy shock considered. We show now the conditions under which these results could differ. We assume in a first counterfactual that the EU quota for Canadian beef imports is binding (100%) at the benchmark (different from the actual) and that the final IQTR is only halved and not set to zero. The MAcMap approach would consider the OQTR as the initial AVE because any fill rate of equal or higher than 98% is considered overfill. The MCP approach depicts a regime where the rent is endogenously determined and benchmarking of the model requires choosing this rent, which is taken as the average of the IQTR and OQTR (similar to what MAcMap assumes under a filled quota). The reduction to the IQTR of 10% is now double as large under the AVE approach (from OQTR to IQTR) compared with the explicit TRQ representation (from [OQTR + IQTR]/2 to IQTR). Now, the substitution effects between disaggregated products in the overall MEAT sector are likely because the original IQTRs are different such that disaggregated products experience different tariff reductions. Figure 9 shows the expected differences between the approaches: the AVE representation now generates stronger impacts than an explicit TRQ regime, particularly for the meat aggregate. Now, the projected trade impact also differs across meat products (Figure 10), thereby reflecting a different percentage reduction in tariffs, which is in contrast to the projected results in Figure 6.

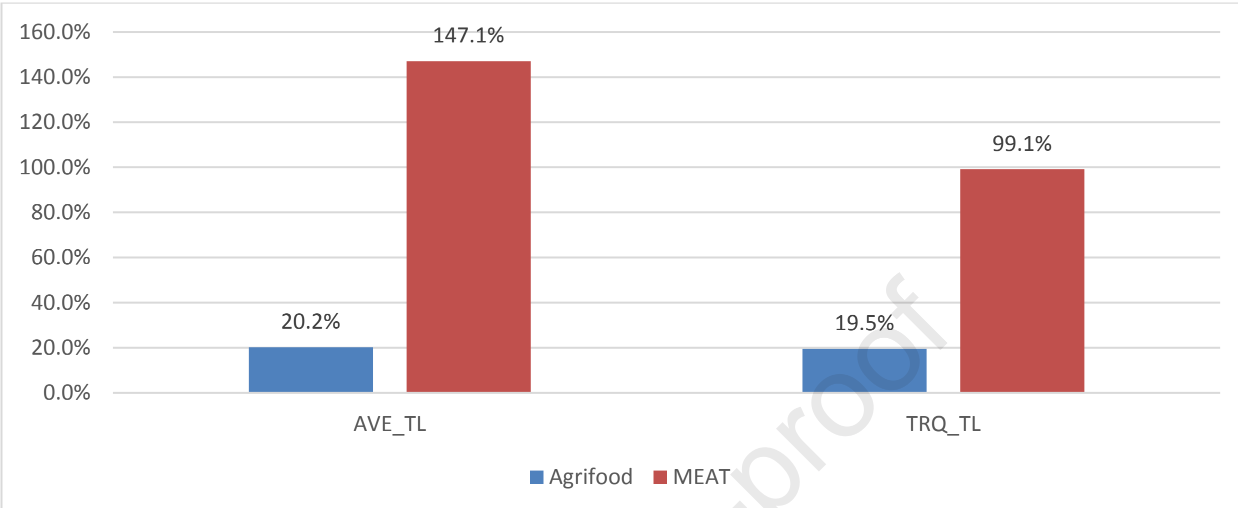


Figure 9. Explicit vs. Implicit treatment of TRQs under the first counterfactual scenario (TRQ fill ex-post, IQTR reduced to 10%)

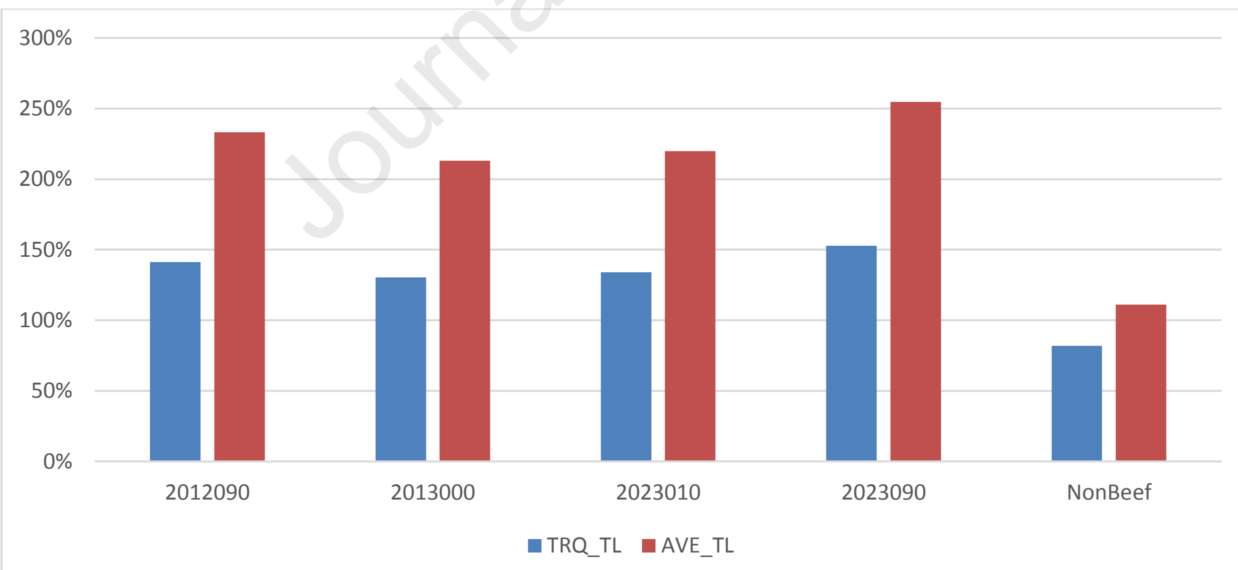


Figure 10. Changes across tariff lines under the first counterfactual scenario (TRQ fill ex-post, IQTR reduced to 10%)

Significant differences in results can emerge if the observed TRQ regime used by MAcMap to calculate the AVE differs from the simulated regime under an explicit TRQs implementation. To demonstrate this point, we assume in a second counterfactual that the quota is expanded by only 20%. With an observed fill rate at 100%, MAcMap assumes a new fill rate of 100/120, which is below the 90%–98% range, where a binding quota is assumed. Accordingly, the IQTR will be used as the new AVE. The simulation with the explicit TRQ representation yields a rent within the range between the new IQTR and OQTR rates because a binding quota is simulated. This results in a smaller simulated trade impact under an explicit TRQ treatment (Figure 11).

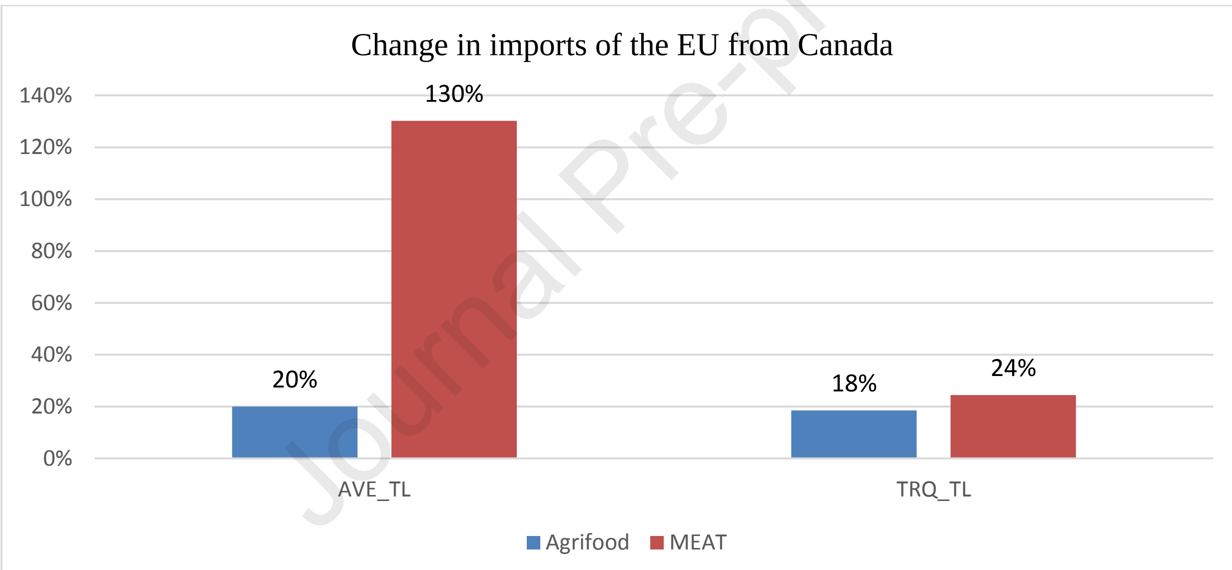


Figure 11. Explicit vs. implicit treatment of TRQs under the second counterfactual scenario (100% fill rate ex-post, 20% TRQ expansion)

Finally, we provide another counterfactual where both the dairy and meat sectors show an initial fill rate of 80% to ensure that both the MCP and MAcMap consider IQTR as the same initial tariff rate for benchmarking. The scenario now considers changes in another policy impacting trade, here assumed as reduced NTMs captured by changes in the Armington share parameter reflecting a demand shift (see e.g., Jafari and Britz, 2018; Jafari, Britz and Beckman, 2019). Figures 12 and

13 indicate the impacts on meat and dairy imports, assuming an increase in the share parameter between 1% and 11%. Here, the MCP and MAcMap approaches project the same trade changes, provided that the NTM reduction leads to a shift of less than 5% and 7% for the meat and dairy demand, respectively. Beyond this point, the AVE approach estimates quota overfill and thus higher impacts. However, the simulated over quota imports are inconsistent with the assumed AVE based on the IQTR.

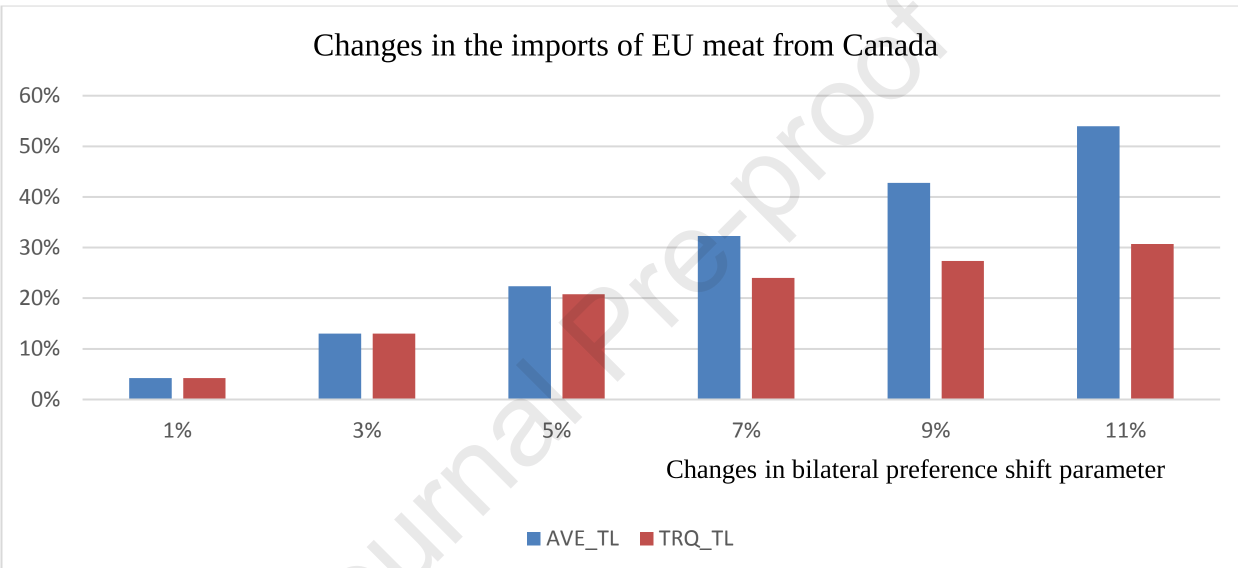


Figure 12. Sensitivity analysis on the impact of NTMs reduction on meat import

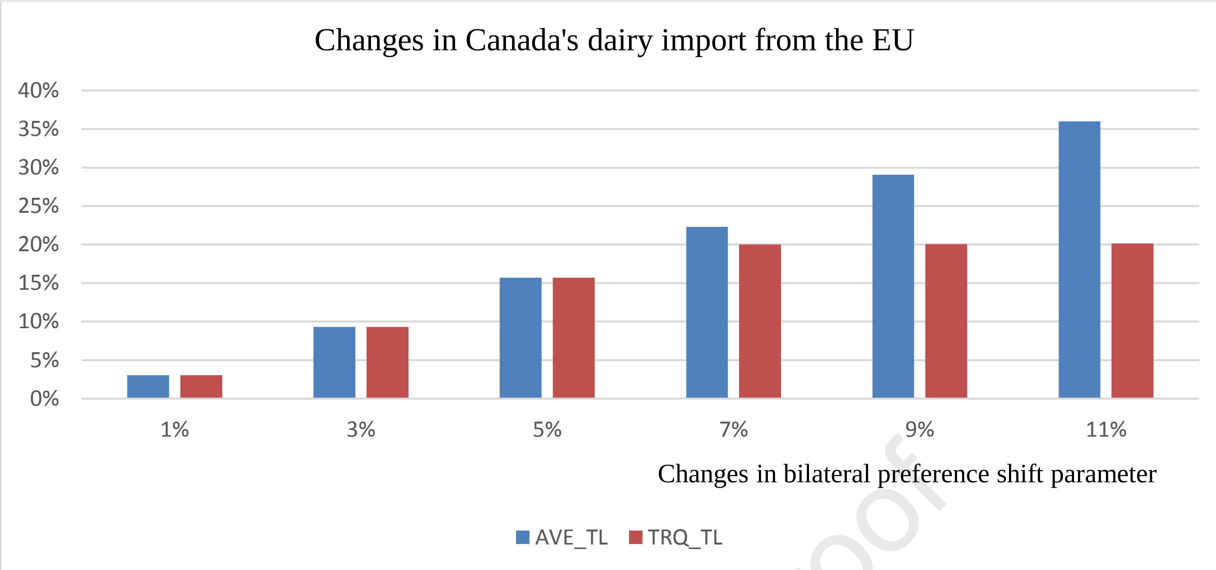


Figure 13. Sensitivity analysis on the impact of NTMs reduction on dairy import

7. Conclusion and remarks

CGE models are quantitative models widely used to analyze the economy-wide impacts of trade policies; however, they are often criticized for simplifying real-world behavior. One reason for this is that the implementation of trade policy instruments is challenging. TRQs provide an example that is discussed here in detail. Another reason is that trade policy is typically defined at some detail, which exceeds the usual product resolution of CGE models. This study addresses these issues by drawing on an approach for bilateral trade modeling at the tariff line based on Jafari et al. (2021), which is now expanded to explicitly capture TRQ regimes based on MCP.

The study results indicate that the proposed approach can remove inconsistencies in two more standard approaches that either convert TRQs to an *ad-valorem* equivalent tariff by using the widely used MAcMap approach or implement TRQs at more aggregate sector level. The MCP approach endogenously depicts the TRQ regime, that is, the simulated marginal tariff depends on the endogenously simulated quota fill rate. Considering the tariff line detail prevents the construction of aggregated TRQs comprising actual TRQs in different initial regimes (i.e., underfill, binding, and overfill), thereby allowing the consideration of differences in IQTR and OQTR rates and quota rents. This avoids cases where trade not under a TRQ becomes subject to an aggregate TRQ regime. Furthermore, the tariff line detail allows for the consideration of substitution in trade between products falling under the same aggregate sector in the CGE model. The MAcMap approach determines the marginal protection rate pre-model based on the observed trade; the resulting AVE is exogenous to the CGE model itself, which can lead to inconsistencies if the simulated trade quantities do not match the TRQ regime used to the calculate the AVE. In particular, a TRQ expansion at unchanged trade quantities often implies that a zero IQTR is used as the AVE. If the original TRQ regime was overfill or a binding quota, the CGE model likely responds to the drop in the AVE with a trade expansion beyond the quota, where the typically prohibitive OQTR would be applied instead.

We use the CETA agreement as an example to demonstrate the potential bias associated with the more common approaches. First, when TRQs are explicitly modeled at an aggregated sector level, we find lower trade impacts compared with the AVE approach, which predicts a larger reduction in marginal tariff rates. Second, we find that modeling at the aggregate level, with explicit TRQs or AVEs, leads to lower trade impacts than when considering the product detail in the model itself. The primary reason is that because some trade is subjected to TRQs and others to normal tariffs, aggregating TRQs and normal tariffs dampen the shock, and thus underestimate the trade impacts. Third, we compare the trade impacts under both TRQ modeling approaches at a disaggregated level but use different substitution elasticities across products falling under the aggregated sector. Our results show that the simulated impacts increased with higher possibilities of substitution among detailed products on the same trade link.

We also performed three counterfactuals. In the first, we show that when the quota is initially filled, but not overfilled and the IQTR is lowered, the AVE approach shows larger changes. This reflects that the MAcMap approach assumes the maximal per unit quota rent (the difference between OQTR and IQTR) once the fill rate exceeds 98%. The MCP approach choses the initial per unit rent instead; in general, the selected marginal tariff rate is lower, such as in the usual assumption to use the average of initial IQTR and OQTR. In a second counterfactual, we show a case where the AVE approach predicts a different TRQ regime ex-ante than when simulated with the model. In this example, the quota expansion lets the MAcMap approach assume that the IQTR will be the new marginal tariff rate. The model responds with an expansion of trade beyond the quota, where the OQTR would apply instead. Similarly, we show that if the quota and related tariffs remain unchanged but another trade policy changes (here a reduction in NTM is used, which shifts import demand), similar inconsistencies can be found; here, trade exceeded the quota in some experiments, whereas the exogenous marginal tariff rate was lower than the OQTR.

Despite the combination of explicit TRQ representation and bilateral tariff line detail, potential for improvements remain. First, because a single TRQ often relates to multiple products at the HS6 or even deeper classifications, depicting TRQs at the tariff line can require an ex-ante allocation of the overall quota to these tariff lines. We propose, but do not implement in our empirical application, a framework to do so endogenously, where a virtual export agent allocates quotas to different tariff lines to maximize revenues. However, this requires the marginal willingness to pay at the tariff line level by the export partner, which is unfortunately not easily obtainable. Future studies might expand on this, for instance, with econometric work. Second, the endogenous TRQ allocation approach could be extended to erga-omnes TRQs, which require import demand and export supply equation systems for all trading partners delivering into such a TRQ. Third, as found in our empirical example, even products at a fine-grain tariff line level may fall under different TRQs. With our 8-digit-level detail trade data, we were not always able to associate each TRQ to a single tariff line. Here, further data might help. Fourth, although our approach captures bilateral trade changes at the detailed commodity level, production changes are not simulated at this detail as, for example, in the GTAP-HS-TRQ model. Finally, for benchmarking under a binding quota when TRQs are implemented explicitly, an assumption on the per unit quota rent must be made. In this study, we took the average of the IQTR and the OQTR, following the MAcMap approach.

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Appendix A. Supplementary Tables

Table A1. TRQs by market

Country	Number of TRQs	Quota Size(tons)	TRQ Imports (tons)	TRQ imports ($1000, estimated)
Australia	2	22,684	12,324	109,632
Barbados	36			
Brazil	2	760,000	6,108,073	2,130,699
Canada	22	885,825	431,738	693,984
Chile	1	60,000		
China	10	25,282,000	14,315,597	4,639,051
Columbia	67	1,495,041	7,682,462	2,767,557
Costa Rica	27	3,378	795	37
Dominican Republic	8	1,208,560	123,628	
European Union	117	19,434,470	9,176,406	
Ecuador	14	55,035		
El Salvador	11	785	156	487
Guatemala	22	107,275	347,943	
Iceland	90	87,172	139,728	185,568
India	4	510,000	19,972	30,293
Indonesia	2			
Israel	12	492,208	1,836,389	511,622
Japan	20	8,602,702	8,213,786	6,885,841
Macedonia	1	80,000	49,863	18,247
Malaysia	19	75,443	68,477	113,340
Mexico	11	20,000	244,040	758,012
Moldova	3	8,340	7,406	5,234

Morocco	19	2,326,390	2,304,357	1,535,764
New Zealand	3	3,331	4,572	6,503
Nicaragua	9	24,776	18,987	4,631
Norway	232	42,746	38,373	118,730
Panama	19	26,196	18,756	51,152
Philippines	14	732,459	587,217	329,693
Russia	9	1,379,000	1,184,887	3,579,436
South Africa	53	1,130,106	716,348	752,909
South Korea	67	9,028,552	8,238,916	3,596,579
Switzerland	28	1,499,975	1,600,106	5,092,451
Taiwan	22	260,884	176,182	
Thailand	23	60,559	98,310	241,346
Tunisia	13	1,239,691	127,029	468,888
Ukraine	1	267,800		
United States	54	2,452,547	1,736,524	4,425,351
Venezuela	61	4,854,614	4,133,289	3,453,380
Vietnam	3	347,526	278,500	291,300

Source. Beckman et al. 2021.

Notes. Quota sizes and TRQ imports (value and volume) reflect information from the Member country's most recent WTO TRQ notification.

Table A2. Description of tariff line commodities

Tariff line	Description
04061020	Cheese and curd. - Fresh (unripened or uncured) cheese, including whey cheese, and curd - Over access commitment
04062012	Cheese and curd. - Grated or powdered cheese, of all kinds - Cheddar and Cheddar types: - Over access commitment
04062092	Cheese and curd. - Grated or powdered cheese, of all kinds - Other: - Over access commitment
04063020	Cheese and curd. - Processed cheese, not grated or powdered - Over access commitment
04064020	Cheese and curd. - Blue-veined cheese and other cheese containing veins produced by Penicillium roqueforti - Over access commitment
04069012	Cheese and curd. - Other cheese - Cheddar and Cheddar types: - Over access commitment
04069022	Cheese and curd. - Other cheese - Camembert and Camembert types: - Over access commitment
04069032	Cheese and curd. - Other cheese - Brie and Brie types: - Over access commitment
04069042	Cheese and curd. - Other cheese - Gouda and Gouda types: - Over access commitment
04069052	Cheese and curd. - Other cheese - Provolone and Provolone types: - Over access commitment
04069062	Cheese and curd. - Other cheese - Mozzarella and Mozzarella types: - Over access commitment
04069072	Cheese and curd. - Other cheese - Swiss/Emmental and Swiss/Emmental types: - Over access commitment
04069082	Cheese and curd. - Other cheese - Gruyere and Gruyere types: - Over access commitment
04069092	Cheese and curd. - Other cheese - Other: - Havarti and Havarti types, Over access commitment
04069094	Cheese and curd. - Other cheese - Other: - Parmesan and Parmesan types, Over access commitment
04069096	Cheese and curd. - Other cheese - Other: - Romano and Romano types, Over access commitment
04069099	Cheese and curd. - Other cheese - Other: - Other, Over access commitment
02011000	Meat of bovine animals, fresh or chilled: Carcasses and half carcasses
02012020	Meat of bovine animals, fresh or chilled: Other cuts with bone in - Compensated quarters
02012030	Meat of bovine animals, fresh or chilled: Other cuts with bone in - Unseparated or separated forequarters
02012050	Meat of bovine animals, fresh or chilled: Other cuts with bone in - Unseparated or separated hindquarters
02012090	Meat of bovine animals, fresh or chilled: Other cuts with bone in - Other
02013000	Meat of bovine animals, fresh or chilled: Boneless - high quality
02021000	Meat of bovine animals, frozen: Carcasses and half carcasses
02022010	Meat of bovine animals, frozen: Other cuts with bone in - Compensated quarters
02022030	Meat of bovine animals, frozen: Other cuts with bone in - Unseparated or separated forequarters
02022050	Meat of bovine animals, frozen: Other cuts with bone in - Unseparated or separated hindquarters
02022090	Meat of bovine animals, frozen: Other cuts with bone in - Other
02023010	Meat of bovine animals, frozen: Boneless - Forequarters, 'compensated' quarters, and hindquarter

02023050	Meat of bovine animals, frozen: Boneless - Crop, chuck-and-blade and brisket cuts
02023090	Meat of bovine animals, frozen: Boneless - Other
02061095	Edible offal of bovine animals, swine, sheep, goats, horses, asses, mules or hinnies, fresh, chilled or frozen: Of bovine animals, fresh or chilled - Other, Thick skirt and thin Skirt
02062991	Edible offal of bovine animals, swine, sheep, goats, horses, asses, mules or hinnies, fresh, chilled or frozen: Other - Thick skirt and thin Skirt
02102010	Meat and edible meat offal, salted, in brine, dried or smoked; edible flours and meals of meat or meat offal: Meat of bovine anima - ith bone in
02102090	Meat and edible meat offal, salted, in brine, dried or smoked; edible flours and meals of meat or meat offal: Meat of bovine anima - Boneless
02109951	Meat and edible meat offal, salted, in brine, dried or smoked; edible flours and meals of meat or meat offal: Other offal - Thick skirt and thin Skirt
02109959	Meat and edible meat offal, salted, in brine, dried or smoked; edible flours and meals of meat or meat offal: Other offal - Other

Source. The definition of tariff lines by the EU available from TARIC (the integrated Tariff of the European Union) database[22], and by Canada available from Canada border Services Agency.[23]

[22] https://ec.europa.eu/taxation_customs/dds2/taric/taric_consultation.jsp?Lang=en
[23] https://www.cbsa-asfc.gc.ca/trade-commerce/tariff-tarif/2015/html/tblmod-2-eng.html

Table A3. Correspondence between tariff lines at 8-digit-level in Canada and the EU

MIL		**MEAT**	
Canada (Importer)	EU (Exporter)	EU (Importer)	Canada (Exporter)
04061020	04061030	02011000	02011020
	04061050	02012020	
	04061080	02012030	
04062012	04062000	02012050	
04062092	04062000	02012090	
04063020	04063010	02013000	02013020
	04063031	02021000	02021020
	04063039	02022010	02022020
	04063090	02022030	
	04064010	02022050	
	04064050	02022090	
	04064090	02023010	02023020
04069012	04069021	02023050	
	04069023	02023090	
04069022	04069082	02061095	02061000
4069032	04069084	02062991	02062100
04069042	04069025		02062200
	04069029		02062900
	04069074	02102010	02102000
	04069078	02102090	
04069052	04069073	02109951	02109990
04069062	04069050	02109959	
04069072	04069013		

	04069017		
	04069018		
04069082	04069015		
	04069035		
04069092	04069075		
	04069076		
04069096	04069061		
	04069063		
04069099	04069001		
	04069032		
	04069037		
	04069039		
	04069069		
	04069079		
	04069081		
	04069085		
	04069086		
	04069089		
	04069092		
	04069093		
	04069099		

Source. Authors compilation based on the definition of tariff lines by the EU available from database, and by Canada available from Canada border Services Agency.

Table A4. Trade value and AVEs across tariff lines

	Canada import of Meat from EU				EU import of Mil from Canada		
Product Code	Pre-CETA AVEs(%_	Post-CETA AVES (%)	Trade Value (USD)	Product Code	Pre-CETA AVEs(%_	Post-CETA AVES (%)	Trade Value (USD)
02011000	26.50	0	0	04061020	4.66	0	0
02012020	26.50	0	0	04062012	3.49	0	0
02012030	26.50	0	0	04062092	3.49	0	0
02012050	26.50	0	0	04063020	3.13	0	0
02012090	26.50	0	0	04064020	1.70	0	42
02013000	26.50	0	0	04069072	3.08	0	902
02021000	26.50	0	0	04069012	2.85	0	5672052
02022010	26.50	0	0	04069082	2.90	0	0
02022030	26.50	0	0	04069062	2.71	0	0
02022050	26.50	0	0	04069094	3.38	0	0
02022090	26.50	0	0	04069096	3.38	0	0
02023010	26.50	0	0	04069052	2.71	0	0
02023050	26.50	0	0	04069092	2.71	0	0
02023090	26.50	0	0	04069042	2.71	0	26978
02061095	0	0	0	04069022	2.71	0	0

02062991	0	0	0	04069032	2.71	0	0
02102010	0	0	0	04069099	2.89	0	148566
02102090	0	0	0				
02109951	0	0	0				
02109959	0	0	0				
TRQMeat_Can	0	0	0	TRQMil_EU	2.85	0.00	5848541
NonTRQMeat_Can	0.58	0	84645858	NonTRQMil_EU	2.51	0.00	576327

Source. Authors' compilation based on the definition of tariff lines by the EU available from TARIC database, and by Canada available from Canada border Services Agency.

Table A5. Possible allocation of tariff lines to TRQs

HS8 code	Fresh meat TRQ	Frozen Meat TRQ	High Quality Meat TRQ	Bison TRQ
02011000	x		x	x
02012020	x		x	x
02012030	x		x	x
02012050	x		x	x
02012090	x		x	x
02013000	x		x	x
02021000		x	x	x
02022010		x	x	x
02022030		x	x	x
02022050		x	x	x
02022090		x	x	x
02023010		x		x
02023050		x		x
02023090		x		x
02061095	x		x	x
02062991		x	x	x
02102010		x		x
02102090		x		x
02109951		x		x
02109959		x		

Source. Authors' compilation based on the definition of tariff lines by the EU available from TARIC database, and by Canada available from Canada border Services Agency

Appendix B. Endogenous allocation of quota

Trade negotiations often determine a 'collective' quota for each of the product categories that have some similarities. For example, CETA determines three types of quota for different classifications of meats: bison, fresh, frozen, and HQB meat and a single quota for the Cheese. Each of the categories comprises some products at finer details and their share in the collective quota is not predetermined. The shares depend on endogenous variables (e.g. prices) and exogenous parameters (e.g. substitution elasticities at the tariff line) that affect the profit of exporters. Given this background, modeling TRQs for ex-ante policy analysis is challenging as one has to allocate the collective quota to each tariff line either exogenously or endogenously. While one could simply allocate the quota equally or proportionally based on observed trade data to the detailed tariff line levels, we present an approach that allows for the endogenous allocation of the shares.

Let q denote a given tariff rate quota accessible to a representative exporting firm that can be filled by tl different tariff lines. The firm has shipped amounts $\bar{x}$ of these different products tl to the export destination at given CIF cost $PMTL_{s,tl,r}^{cif}$ and receives related prices $PMTL_{s,tl,r}$ by selling at the export destination, and has to pay the yet to determine tariffs. The OQTR, t^{oq} differ across the tariff lines while IQTR is zero. The problem is to determine which amounts of the different x are formally declared to fall under the quota and if the firm shall sell the rest or not. The problem is hence,

$$\max \pi = \sum_{tl} x_{tl,oq}\left[\overline{PMTL_{s,tl,r}} - \overline{t_{tl}^{oq}}\,\overline{PMTL_{s,tl,r}^{CIF}}\right] + x_{tl,iq}\,\overline{PMTL_{tl}} - \overline{x_{tl}}\,\overline{PMTL_{s,tl,r}^{CIF}} \qquad \text{(C.1)}$$

$$\begin{aligned} s.t. \quad & x_{tl,oq} + x_{tl,iq} \le \overline{x_{tl}} \quad [\lambda_{tl}] \\ & \sum_{tl} x_{tl,iq} \le \bar{q} \qquad [\lambda_q]. \end{aligned}$$

where the profit π, to be maximized, depicts the difference between the revenues received by selling the product at the export destination and the cost that includes the tariff. The first set of constraints state for each of the different product that the purchased quantity must be declared as in-quota *iq* or out-of-quota *oq*, potentially in shares. The second set of constraints ensures that the quota is filled. This is a simple linear problem that we can solve *via* Lagrange multipliers,

$$\frac{\partial L}{\partial x_{tl,oq}} = \overline{PMTL_{s,tl,r}} - \overline{t_{tl}^{oq}}\,\overline{PMTL_{s,tl,r}^{CIF}} - \lambda_{tl} \perp x_{tl,oq} \qquad \text{(C.2)}$$

$$\frac{\partial L}{\partial x_{tl,iq}} = \overline{PMTL_{tl}} - \lambda_{tl} - \lambda_{q} \perp x_{tl,iq}.$$

We have two expressions for the λ_{tl} which can be combined to get,

$$\lambda_{tl} = \overline{PMTL_{s,tl,r}} - \overline{t_{tl}^{oq}}\,\overline{PMTL_{s,tl,r}^{CIF}} = \overline{PMTL_{tl}} - \lambda_{q}. \qquad \text{(C.3)}$$

Rearrange Equation (C.3) to find the optimal quota rent gives

$$\lambda_{q} = \overline{t_{tl}^{oq}}\,\overline{PMTL_{s,tl,r}^{CIF}} \perp x_{tl,oq}, \qquad \text{(C.4)}$$

This implies that the uniform quota rent is defined by the per unit tariff costs which must be equalized across the different products falling under the same quota.

Let us assume that we have only two products. We would only export over-quota quantities of a product if the difference between the price received $\overline{PMTL_{tl}}$ and the cost $(1+\overline{t_{tl}^{oq}})\overline{PMTL_{tl}^{CIF}}$ is positive. The product with the smallest positive difference defines the quota rent λ_{q}, and its λ_{tl} is exactly zero. Products with higher positive differences have an extra value of λ_{tl} which can be interpreted as additional economic rent. The firm would rather export these products over quota, either because they have a lower *ad-valorem* tariff or lower production cost. Note that in the above maximization problem we assumed that the representative firm has already shipped the products to the destination and then realizes the quota to be filled, such in case of a first-come-first-serve quota, this includes the case to dispose of quantities instead of selling them. That is the case if the $\overline{t_{tl}^{oq}}\,\overline{PMTL_{tl}^{CIF}} > \overline{PMTL_{tl}} - \overline{PMTL_{tl}^{CIF}}$, i.e. if the difference between the per unit revenues from selling minus the sunk c.i.f. costs are smaller from the tariff to pay to be allowed to sell.

To use the results in the context to define appropriate AVE rates, this suggests using the highest AVE rate which at given CIF price would still be able to be sold in the export market. This requires information in the marginal willingness to pay at the tariff line level by the export partner that is unfortunately not easily obtainable.

Highlights for

Properly capturing tariff rate quotas for trade policy analysis in computable general equilibrium models

- Computable General Equilibrium analysis often simplifies Tariff rate quotas (TRQs)
- We propose to implement the TRQ mechanism explicitly at detailed product level
- Biased outcomes result if TRQs are implemented at aggregate sectoral level instead
- The same holds if TRQs are implicitly represented by Ad Valorem Equivalents
- We therefore recommend explicit representation of TRQs at detailed level

Properly capturing tariff rate quotas in trade liberalization: Impacts of CETA

Yaghoob Jafari[1], Wolfgang Britz[1], Houssein Guimbard[2], Jayson Beckman[3]

[1]Institute for Food and Resource Economics (ILR), University of Bonn, Germany

[2]CEPII (Centre d'Etudes Prospectives et d'Informations Internationales), Paris, France

[3]Economic Research Service, United States Department of Agriculture (USDA)

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