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To my wife who sacrificed the most to get this thesis done

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Abstract

The success of the Uruguay Round of multilateral trade negotiations revealed the political viability and economic importance of global trade liberalization. Although subsequent multilateral negotiations have been less successful, many countries aim to further liberalize trade, often by negotiating regional free trade agreements. The further development of existing quantitative tools for economic impact assessment of trade policies, thus, seems as relevant as ever. This thesis improves the representation of trade policy instruments in global applied equilibrium models (AEM) reflecting on recent improvements in numerical algorithms and computational power, better statistical information at global scale and unresolved theoretical challenges. Regarding the ex-ante availability of trade negotiation details, we look at two extremes. First we consider that highly detailed information is available and use tariff line level data to extend existing AEMs. On the other extreme, we assess future trade agreements without such detailed information. Lacking detailed policy input data, we use broader negotiation objectives to design an exploratory policy analysis with a typical, large-scale AEM. Even if based on imprecise assumptions, such impact assessments still can provide crucial input for policy making. More so as trade policies interact with other areas of international cooperation, such as global efforts to combat climate change; interplays which have received increased public and scientific attention.

For both extremes of policy data availability, methodological improvements to AEMs are proposed. Assuming fully detailed information, a tariff aggregation method is developed that is consistent in terms of simulated welfare-implications while remaining invariant to geographical details on exporting countries. Consistent tariff aggregation eliminates the aggregation bias, but only in terms of one selected model outcome. To increase precision in more than one simulated impacts we also look for multi-purpose alternatives to consistent aggregation. Two multi-purpose aggregation approaches are presented with a focus on correcting for the following biases: (i) the substitution effect at the tariff line; (ii) the imperfect transmission of tariff cuts to domestic import prices (water in tariffs) and (iii) the interdependency of tariff rates and imported quantities under Tariff Rate Quota regimes. Concerning a lack of detail on (future) trade policies, we explore the contribution of the current EU trade agenda to global greenhouse gas mitigation efforts for agriculture. The agri-food sector is both a major emitter of non-CO2 gases and characterized by a higher level of border protection. In that setup, a simulation exercise with a large-scale partial equilibrium model (CAPRI) reveals potentially significant emission leakage impacts, and thus trade liberalization negatively contributes to unilateral emission mitigation efforts.

The thesis thus includes several empirical examples, demonstrating that the proposed improvements for trade policy modelling can be implemented in current, even large-scale, modelling systems, and they significantly improve simulation results. We also highlight some future challenges related to the assessment of trade agreements in a wider policy context such as within the trade-climate change nexus.

Keywords: tariff aggregation, trade liberalization, Tariff Rate Quota, trade and climate change nexus, greenhouse gas emissions, emission leakage, CAPRI

Kurzfassung

Der Erfolg der Uruguay-Runde verdeutlichte, dass globale Handelsliberalisierung politisch realisierbar und ökonomisch bedeutend sein kann. Nachfolgende Verhandlungen innerhalb der Welthandelsorganisation (WTO) waren zwar weniger erfolgreich, aber viele Länder streben nach weiterer Handelsliberalisierung, häufig durch regionale Freihandelsabkommen. Deshalb ist die Weiterentwicklung von quantitativen Methoden und Modellen zur wirtschaftlichen Folgenabschätzung von Handelspolitiken weiterhin relevant. Ziel dieser Dissertation ist die Verbesserung der Modellierung handelspolitischer Maßnahmen in globalen angewandten Gleichgewichtmodellen (AEM), unter Berücksichtigung aktueller Entwicklungen in numerischen Analyseverfahren und Rechenleistungen, besseren internationalen statistischen Informationen und ungelösten theoretischen Herausforderungen. Bezüglich der Vorabverfügbarkeit von Informationen zu Handelsabkommen werden zwei Gegensätze betrachtet. Wenn detaillierte Informationen verfügbar sind benutzen wir Daten auf Zolltarifpositionsebene um AEMs zu erweitern. Anschließend bewerten wir zukünftige Handelsabkommen bei denen diese Details nicht verfügbar sind. Anstatt detaillierte vorhandene Daten verwenden wir hierfür allgemeine Verhandlungsziele um eine Analyse mit einem typischen allgemeinen AEM zu gestalten. Selbst wenn sie auf unpräzisen Annahmen beruhen, können solche Analysen wichtige Beiträge für die Politikgestaltung liefern, insbesondere da Handelspolitiken sich auch auf andere Bereiche der internationalen Zusammenarbeit auswirken, wie zum Beispiel die globalen Anstrengungen zur Bekämpfung des Klimawandels.

Für beide Gegensätze der Datenverfügbarkeit werden in dieser Dissertation methodische Verbesserungen für AEMs vorgeschlagen. Zunächst wird eine Zollaggregationsmethode entwickelt die konsistent bezüglich der simulierten Wohlfahrtsauswirkungen und gleichzeitig invariant zu geographischen Details der Ausfuhrländer ist. Konsistente Zollaggregation verhindert Aggregationsverzerrungen, allerdings nur für eine ausgewählte Modellergebnisvariable. Um die Genauigkeit der simulierten Ergebnisse bei mehreren Variablen gleichzeitig zu verbessern werden auch Mehrzweckalternativen zur konsistenten Zollaggregation untersucht. Zwei Aggregationsmethoden werden getestet mit dem Ziel die folgenden Verzerrungen zu verringern: (i) der Substitutionseffekt auf Ebene der Zolltarifpositionen; (ii) die imperfekte Transmission der Tariffsenkungen auf inländische Importpreise und (iii) die gegenseitige Abhängigkeit zwischen Importzöllen und Einfuhrmengen unter Zollquoten. Bezüglich Handelspolitikbewertung im erweiterten politischen Kontext analysieren wir den Beitrag der aktuellen EU Handelspolitikagenda zu den internationalen Bemühungen bei der Verringerung landwirtschaftlicher Treibhausgasemissionen. Simulationen mit dem partiellen Gleichgewichtsmodel CAPRI zeigen erhebliche Emissionsverlagerungen durch die geplanten Handelsabkommen, d.h. unilaterale Verringerungen von EU Treibhausgasemissionen könnten auf globaler Ebene untergraben werden.

Diese Dissertation enthält mehrere empirische Beispiele die aufzeigen, dass die vorgeschlagenen Verbesserungen zur Modellierung von Handelspolitiken in existierende Modellierungssysteme implementiert werden können und zu deutlich verbesserten Simulationsergebnissen führen. Zudem werden einige zukünftige Herausforderungen der Handelspolitikanalyse in einem erweiterten politischen Zusammenhang, wie zum Beispiel im Rahmen des Welthandel-Klimawandel Nexus, hervorgehoben.

Schlusselwörter: Zollaggregation, Handelsliberalisierung, Zollquoten, Welthandel-Klimawandel Nexus, Treibhausgasemissionen, Emissionsverlagerungen, CAPRI

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Abbreviations

AEM	Applied equilibrium model (here covering numerical simulation models based on the general equilibrium theory)
AVE	Ad valorem Equivalent
CGE	Computable General Equilibrium model
ETS	Emission Trading System
EU	European Union
FAO	Food and Agricultural Organization of the United Nations
FTA	Free Trade Agreement
GE	General equilibrium
GHG	Greenhouse gas
IPCC	Intergovernmental Panel on Climate Change
MAcMap	Market Access Map database from the International Trade Centre
MTRI	Mercantilist Trade Restrictiveness Index
NDC	Nationally Determined Contributions in the Paris Agreement
NTM	Non-tariff measures
PE	Partial equilibrium
TE aggregator	Trade Expenditure aggregator
TRI	Trade Restrictiveness Index
TRIMAG	Tariff Reduction Impact Model for Agriculture
TRQ	Tariff Rate Quota
WTO	World Trade Organization

Chapter 1: Introduction and overview of the thesis

1.1 Introduction

Implementing border protection policies, such as tariffs, quantitative restrictions or other non-tariff measures, requires a certain level of aggregation in contemporary applied equilibrium models (AEM) of international trade. Different data availability on trade flows and tariffs versus supply and consumption is one reason that forces practitioners to aggregate. Trade statistics and current trade policy instruments (including the outcome of trade negotiations, such as tariff schedules) typically are available, or even defined, at the detailed level of tariff lines (Guimbard et al., 2012), while statistics on supply and consumption are only available for more aggregated commodities. Technical limitations on computational power and numerical algorithms also force modellers to build aggregate databases for their AEMs, both geographically and commodity-wise.

The last decade has brought a rapid development in trade modelling, both by relaxing computational limitations and with the availability of ever more detailed trade statistics at the global scale. The straightforward way for better exploiting the possibilities these trends offer would be to extend trade models to the tariff line, and to avoid aggregation as much as possible. There are indeed some attempts in the literature pushing the computational limits towards more geographical and product-wise disaggregation. (Grant et al., 2007) extends a rather aggregated Computable General Equilibrium (CGE) model with a satellite partial equilibrium (PE) model working at the tariff line for dairy products. (Narayanan et al., 2010) opt for a fully nested approach for extending a CGE model to include commodities at tariff line level for the impact assessment of the tariff liberalization for the Indian auto industry. (Britz and van der Mensbrugghe, 2016) advocates advanced database filtering and improved numerical algorithms to avoid, or at least significantly reduce, pre-model aggregation. These examples, however, still offer only partial solutions, as they either do not cover all modelled sectors and regions or they still do not disaggregate the model to tariff lines. Thus practitioners are confronted day to day with the choice of an appropriate tariff aggregation method that fits both their modelling tools and the objective of their modelling exercise.

Trade modellers borrowed the first ideas for tariff aggregation in their models from the literature of measuring trade protection and restrictiveness. Tariff aggregation was, and often currently is, done by applying weighted averages over the tariff lines, with weights typically related to traded volumes. It was quickly recognized that trade weighted averages are subject to the endogeneity bias, i.e. trade in those goods facing high tariffs tends to be low, resulting in small weights and thus in systematically underestimated aggregate measure of tariff protection (c.f. Pelikan and Brockmeier, 2008). To decrease the bias, trade modellers started using different weighting schemes and even a combination of weighting methods.

Following the classification of(Cipollina and Salvatici, 2008), weighted averages fall into the category of a-theoretic measures of trade restrictiveness, lacking the links to economic theory. In the early nineties, (Anderson and Neary, 1994) started a new branch in the literature for measuring trade protection with the introduction of the so-called consistent measures, and they pioneered tariff aggregation methods consistent with a selected measure of economic activity. The first of such a measure, the Trade Restrictiveness Index (TRI), measured tariff protection and policy restrictions in terms of their impact on the home country's welfare, mapping the deadweight loss associated to border policy instruments in to and index number. As consistent measures were applied to evaluate multilateral trade liberalization proposals at the global scale, and as welfare impacts are not always good predictors for countries' bargaining strategies, a set of consistent aggregators have been later developed focusing on other economic variables too. The Mercantilist Trade Restrictiveness Index (MTRI), for example, measures trade protection in terms of its impact on traded volumes, rather than on domestic welfare.

The TRI can be interpreted as a uniform ad valorem tariff rate that provokes the same welfare impact as the individual tariff line rates. Unfortunately, that uniform tariff rate is not suitable for AEMs, as only one aggregate tariff cannot resolve the tension between the simultaneous marginal impact of tariff changes on tariff revenues and on consumer expenditures. (Bach and Martin, 2001) tackle this problem first, by defining separate aggregators for the expenditure and the tariff revenue functions. (Anderson, 2009) further simplifies and completes their approach by adding an optimal combination of a trade weighted aggregator and a consistent aggregator to the trade balance condition of the general equilibrium framework.

Apart from the endogeneity bias, another side-effect of conventional aggregation methods on simulated welfare and trade impacts, which is less explored in the current literature, is that these simulated impacts can be systematically increased by adding more regional detail to the AEMs database. (Ko and Britz, 2013) demonstrate the systematic bias of geographical aggregation on simulated results in the specific case of modelling the EU-South Korea free trade agreement (FTA) with a CGE model. In Chapter 2 of this thesis we have a closer look at their findings and we successfully extend state-of-the-art tariff aggregation techniques to correct for the systemic bias: we develop a welfare-consistent aggregation approach that is invariant to increasing geographical detail for exporter countries.

Consistent aggregators eliminate aggregation bias in terms of one selected variable, but that does not hold for all simulation outcomes. In fact consistent aggregators might increase the bias in other simulated model outcomes. A welfare consistent aggregator for a tariff reduction, for example, might eliminate aggregation bias in welfare impacts, but can, at the same time, increase aggregation bias in simulated traded volumes. Therefore consistent aggregation methods cannot serve as general-purpose alternatives to a-theoretic trade weighted methods; a reason while the latter approaches are still prevalent in current practice.

In order to develop multi-purpose alternatives to conventional aggregation, we explore in Chapter 3 methodological techniques that borrow ideas from consistent aggregation and apply model-endogenously determined (variable) aggregation weights. Still these techniques do not aim at full consistency with respect to any model variables, but instead they aim at addressing three sources of aggregation bias on a wider range of simulated impacts: substitution effect at the tariff line, water in tariffs and variable tariff rates under Tariff Rate Quota (TRQ) regimes.

We put an emphasis on proposing aggregation techniques that do not require significant changes in existing model structures, and can be implemented as pre-model satellite modules for large-scale AEMs. That property is a serious advantage in practice while changing database or equation structure for large-scale models might require serious human resources.

After improving tariff aggregation for trade policies that are known in detail, the second part of the thesis deals with the assessment of future trade policies or those being currently under negotiation. What makes modelling future trade agreements challenging is that the fine details of the deal are effectively unknown during the negotiation process, and thus trade modellers are forced to design their scenarios following broader negotiating mandates or even more loosely defined negotiation objectives of the parties. In Chapter 4, therefore, we move from exploiting the fine details of tariff line data in AEMs to a more general and more aggregated approach for trade modelling. As trade policies do not operate in isolation, but interact with other policy efforts too, modelling exercises with less specific trade policy assumptions but with strong links to other policy areas can provide insights into policy interactions; and are therefore well justified. In this thesis we focus on the interplay of trade and environmental policies, and we empirically assess the effect of the current EU trade agenda (including FTAs currently negotiated or to be started by the EU) on global greenhouse gas (GHG) mitigation efforts in agriculture. International trade is an important factor in defining the global impact of any local GHG mitigation effort. Emission reduction in one country or region might be partially or totally offset globally by increasing emissions in other parts of the world. Whether emission leakage (i.e. domestic emission savings offset by increased emissions in other parts of the world) increases or decreases due to a trade deal is mainly determined by the relative emission efficiency of the trading partners. GHG mitigation efforts of relatively emission efficient regions (such as the EU) are specifically jeopardized by emission leakage, if those efforts are done unilaterally, without comprehensive multilateral agreements for limiting leakage. As international trade is the transmitter of emission changes to trading partners and to other third countries, the representation of trade policies in AEMs is also crucial for improving simulated environmental impacts of GHG-reduction policies.

Agriculture is a major emitter of non-CO2 (nitrous oxide and methane) gases (Henning et al., 2006) but policies directly limiting agricultural GHGs are still relatively rare. In the EU, for example, agriculture is not part of the Emission Trading System (ETS). Agricultural mitigation efforts are rather driven by the EU Energy and Climate Framework, which sets economy-wide reduction targets for the member states. Member states have then flexibility to set specific targets to their agriculture sector. An EU-wide GHG-reduction policy for agriculture is not (yet) in the policy discussion. The Paris agreement might become a game changer in this respect, in case firmer commitments imply a need for increased contribution from agriculture to combat global warming. The Commission's concept on the future of food and farm (European Commission, 2017) already calls for an increased ambition for the agriculture to contribute to climate change mitigation efforts, and sets bolstering climate mitigation efforts as one of the main objectives of the future Common Agricultural Policy. The future implementation of ambitious nationally determined contributions (NDC) to the Paris Agreement, and reaching reduction targets more efficiently, might require direct mitigation policies in EU agriculture.

In Chapter 4 we assess such a direct emission mitigation policy in the form of a hypothetical EU-wide carbon tax for agriculture. Our focus is not primarily on the efficiency of the carbon tax in reducing agricultural GHG emissions, but rather the international context. More precisely, we investigate whether the ambitious trade liberalization agenda in which the EU is currently engaged, could contribute to GHG mitigation efforts. The Juncker Commission put further trade liberalization as one of its top priorities to boost economic growth and job creation (European Union 2018). But trade liberalization might also magnify emission leakage effects, depending on relative emission efficiencies of the EU main trading partners and on the structure of EU agri-food trade.

With the mean of a comparative static simulation exercise with the CAPRI model we provide some empirical evidence that the trade liberalization agenda leads to significant emission leakage effects and partially offsets globally the emission reduction gains of an EU-wide carbon tax in agriculture. That result hinges on the key assumptions that the EU agriculture is relatively emission efficient, and that the introduction of the carbon tax does not happen in the context of a multilateral emission reduction effort, but rather done unilaterally. That simulation results allow us to formulate some policy recommendations on improving the efficiency of possible future GHG mitigation policies in the EU agriculture.

As the fine details of the EU's future trade agreements are yet unknown, we opt for a simplified trade policy representation in our scenarios. Trade policy instruments (including specific tariffs, TRQs, entry price system) are converted into an equivalent ad-valorem tariff rate, representing the initial price wedges between import prices at the border and those faced by domestic consumers. Although some details of the EU policies are lost with the ad-valorem equivalent representation, this simplification allows for defining rather general trade liberalization assumptions on future tariff cuts that are still of uncertain magnitude. To address the uncertainty in future FTAs of the EU, we also perform a sensitivity analysis regarding the EU's ambition on trade opening. The robustness of the simulated results is tested against more and less ambitious trade liberalization options for the FTA partners. The sensitivity analysis confirms that the main drivers of the simulated emission changes in the EU agriculture are invariant to different level of trade liberalization assumptions.

1.2 From research objective to contributions to literature

In the following section we formulate the main research objectives of the thesis, and introduce the methodological approaches we applied to tackle them. We highlight the methodological advances and empirical contributions to the literature which are further discussed in detail in the remaining chapters.

1.2.1 Flexible and welfare-consistent aggregation over exporters

(Ko and Britz, 2013) draw attention to a specific aggregation bias which is less explored in current literature. They pose the research question whether regional aggregation matters for CGE modelling, and give straight ahead a positive answer. Their paper highlights that simulated trade liberalization impacts systematically increase with more geographical detail (representing the EU with its member states rather than as one aggregate region in this case) in the context of the EU-South Korea FTA. In this thesis we go one step further and demonstrate that although the above bias indeed exists for conventional aggregation methods, it is possible to construct a welfare-consistent aggregation that fully eliminates it, at least for simulated welfare impacts. We construct such an aggregator by extending the (Anderson, 2009) framework for consistent trade policy aggregation in the general equilibrium framework. Caveats certainly apply for the use of the proposed aggregation in practical trade modelling, including limitations on the demand system (separable homotheticity), the small country assumption (i.e. changes in import demand have no impact on world prices) or that the supply of domestically produced goods does not influence domestic consumer prices. We further discuss the implications of these limitations in the subsequent sections.

The (Anderson, 2009) framework builds on the balance of trade condition which guarantees that the value of imports in the economy is equal to the value of exports plus a possible financial inflow b:

$$B(p,\pi,u,\bar{p}^w,\bar{\pi}^w)=E(p,\pi,u)-(p-\bar{p}^w)'E_p-(\pi-\bar{\pi}^w)'E_\pi-b=0. \quad (1.1)$$

Above the trade expenditure function $E()$ is defined as the difference between the consumers' expenditure function and the gross domestic product (GDP) function:

$$E(p,\pi,u)=e(p,\pi,u)-g(p,\pi)$$

where (p,π) denotes the domestic price vector, partitioned to a part to be aggregated (p) and to another one that is not (π). u denotes real income. The Shephard's and Hotelling's Lemmas allow for deriving the excess demand function directly from the expenditure function: $E_p=e_p-g_p$ and $E_\pi=e_\pi-g_\pi$ (the subscripts denote partial derivatives). Consistent aggregation requires restrictions both on the supply and demand sides of the economy. We assume (weakly) separable demand for the product group with price vector p and assume that the group enters the consumers' utility function homothetically. Separable homotheticity implies two-stage budgeting (Deaton and Muellbauer, 1980), and allows the formulation of price indexes over product groups at the top level of the consumers' budget allocation problem. Assuming that domestic prices are wedged away from fix world prices $p=(1+T)\bar{p}^w$ by a tariff vector T, and with the fix utility assumption, one can construct a tariff aggregator for the expenditure part as an implicit function of domestic prices:

$$\phi:\mathbb{R}^n\to\mathbb{R} \mid E(\phi(p),\pi,\bar{u},\bar{p}^w,\bar{\pi}^w)=E(p,\pi,\bar{u},\bar{p}^w,\bar{\pi}^w). \quad (1.2)$$

(Anderson, 2009) builds on the above implicit function and combines two tariff aggregators in an aggregated version of the balance of trade condition of equation (1.1):

$$E(\frac{\phi(\bar{p}^w)}{1-T^\delta},\pi,u)-T^aE_\phi\frac{\phi(\bar{p}^w)}{1-T^\delta}-(\pi-\bar{\pi}^w)'E_\pi-b=0. \quad (1.3)$$

Note that the above equation already refers to aggregated commodity categories. Anderson coins T^δ the True Average Tariff, introduced as the aggregated price wedge relative to the aggregate domestic price:

$$T^\delta=\frac{\phi(p)-\phi(\bar{p}^w)}{\phi(p)}=1-\frac{\phi(\bar{p}^w)}{\phi(p)}.$$

The second aggregator T^a in the optimal combination is a simple trade weighted average tariff.

In Chapter 2 we extend the above framework by introducing a regional dimension for the exporter (partner) countries. We first define exporter-specific implicit functions analogue to equation (1.2):

$$(\varphi_1,\ldots,\varphi_n):\mathbb{R}^{n\times m}\to\mathbb{R}^n \ \mid \ E((\varphi_i(p))_{i=1}^n,\pi,u)=E(p,\pi,u),$$

In general, no unique solution exists for the above equation. By exploiting separable homotheticity, however, we develop a sequential numerical method to derive exporter-specific versions of

Anderson's True Average Tariff and we demonstrate how to combine them in an extended version of the standard balance of trade condition in equation (1.3):

$$E\left[\frac{\varphi_1(\bar{p}^w)}{1-T_1^\delta},\dots,\frac{\varphi_n(\bar{p}^w)}{1-T_n^\delta},\pi,u\right]-\sum_i T_i^a E_{\phi_i}\frac{\varphi_i(\bar{p}^w)}{1-T_i^\delta}-(\pi-\bar{\pi}^w)'E_\pi-b=0.$$

Being able to derive the aggregators in a sequential numerical algorithm, i.e. region after region, is a crucial for reducing the difficulties of the practical implementation of extended aggregation framework. The aggregation can be implemented in a pre-model aggregation module, loosely attached to existing large-scale models. In Chapter 3 we demonstrate how to implement that sequential numerical approach in practice, by developing a pre-model aggregation module for the CAPRI modelling system. With that aggregation module we calculate exporter specific aggregate tariffs for Swiss beef imports directly from tariff line level data.

Although (Anderson, 2009) discusses how to apply his framework for quantitative restrictions (e.g. import quotas), the aggregation framework, to the best of our knowledge, has not yet been extended in the literature to explicitly deal with TRQs. TRQs are two-tiered tariff measures, where imports are subject to a lower in-quota tariff rate until imports reach a pre-defined threshold. Above that quota level a higher out-of-quota tariff rate applies. A further contribution to the literature in Chapter 2 is the extension of the Anderson framework to deal with variable tariff rates under TRQ regimes. We introduce explicit TRQ functions at the tariff line level, which link applied tariff rates to imported quantities.

TRQs do not only pose a challenge for modelling due to the interlinkage between tariff rates and imported quantities. Allowing for different allocation of quota rents between importers and exporters further complicates the extension of the above optimal combination of tariff aggregators. In Chapter 2 we define a combination of not less than seven tariff aggregators in a modified balance of trade condition to aggregate both tariffs and TRQs in a welfare consistent manner.

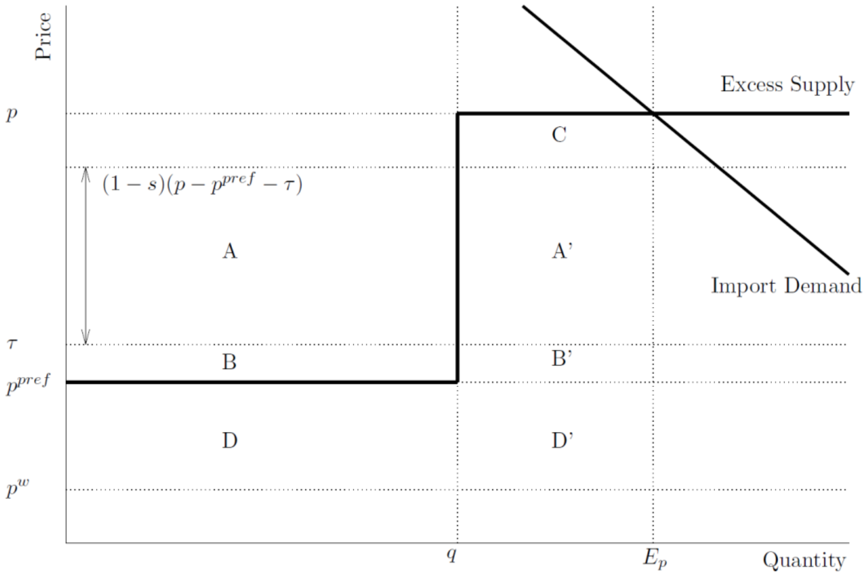
$$\begin{aligned}E(\frac{\phi(p^w)}{1-T^\delta},q,\pi,u)-E_\phi\frac{\phi(p^w)}{1-T^\delta}\left[\hat{T}^a+T^R+\hat{T}^{a,pref}\right]\\ -E_\phi\frac{\phi(p^w)}{1-T^\delta}\left[\hat{T}^{a,corr}-T^{R,corr}\right]+T_q-(\pi-\bar{\pi}^w)E_\pi-b=0.\end{aligned} \tag{1.4}$$

The aggregator T_q in equation (1.4) is a correction term calculated over the quota threshold:

$$T_q=\left[s\left(p-\bar{p}^w\right)-s\tau\right]' qI^{out}=\sum_{j|E_j^{in}>q_j} q_j\left[s_j(\mathrm{p}_j-\bar{p}_j^w)-\mathrm{s}_j\,\tau_j\right].$$

The tariff aggregators are related to the tariff revenues and economic rents accrued to importer or exporters, and can be directly matched with the areas depicted on Figure 1.1, namely: $\left(A+A'+B+B'\right)\sim\left(\hat{T}^a,T^R,T_q\right)$, $C\sim\left(\hat{T}^{a,corr},\hat{T}^{R,corr}\right)$ and $\left(D+D'\right)\sim\left(\hat{T}^{a,pref}\right)$.

Figure 1.1: Quota rents and tariff revenues under TRQ, small country case with an overfilled quota assumption



We give further insight in the empirical implementation of the above aggregation method in Chapter 2 by constructing a small equilibrium model for the South-Korean dairy market. The empirical model includes a nested demand structure over 21 HS6 tariff lines, representing the EU as trade partner both with its member states and also as one regional entity. In a comparative static simulation exercise we demonstrate that our proposed aggregation method indeed eliminates the bias related to increased geographical details for the partner countries. Simulation results are also systematically compared to other, conventional, aggregation methods.

1.2.2 Multi-purpose tariff aggregators

The aggregation method developed in the previous section is only consistent in terms of simulated welfare impacts. The question arises, how much we can sacrifice from full consistency to correct for, or at least improve on typical aggregation biases for a wider range of model variables. Would it be possible to develop aggregation techniques that are, at the same time, cheap to implement in existing models and do not require substantial changes in model structures?

In Chapter 3 we propose two multi-purpose aggregation approaches which are not consistent, unlike the previously presented Anderson framework, but which have potential advantages for applied trade modelling. The proposed approaches improve simulation results in terms of three typical aggregation biases, and with respect to a wider range of model variables, including bilateral trade flows and import prices.

They can also be implemented as pre-model aggregation modules, loosely attached to existing models, without the need for modifying model structures. There is even a room for shifting parts of the policy representation (i.e. TRQ equations) from the core model to the proposed aggregation modules, thereby further reducing the complexity (and computation requirements) of existing models.

Both proposed aggregation methods mimic substitution on the demand side via CES demand systems, but following different approaches. The trade expenditure (TE) aggregator is conceptually identical to the True Average Tariff introduced in the previous section, and is based on a full, nested CES demand system at tariff line level. The Tariff Reduction Impact Model for Agriculture (TRIMAG) aggregator, on the other hand, is a trade-weighted aggregator, but adjusts the aggregation weights according to stylized demand reactions depicted by CES share- and price index equations.

Regarding the aggregation biases we first focus on the substitution effect at the tariff line, an issue linked to the heterogeneity of commodity groups. Trade liberalization often leads to demand side adjustments and altered composition of imported commodity group as import prices of (including the tariff content) might change to different extents. Fix relative import shares within commodity groups is therefore an often too restrictive assumption. The size of the bias crucially depends on the elasticity of substitution within the group and on the relative price changes. Commodity groups with large tariff dispersion or encompassing relatively homogenous goods are subject to a bigger possible bias.

The second source of aggregation bias originates in the imperfect transmission of tariff cuts to domestic import prices. We refer to the part of the applied tariff rate that needs to be eroded before tariff cuts start to have impact on domestic price as the “water” in tariffs. This is somewhat different from the standard binding overhang definition in literature, which is the difference between bound and applied rates (e.g. (Bchir et al., 2006)). Both definitions of tariff "water" refer to the buffer that countries have in trade negotiations, i.e. they can lower bound tariffs without impacting current applied tariffs and thus their domestic prices. Conventional tariff aggregation techniques are based on price wedges and they calculate domestic prices simply by adding applied tariffs on top of world prices. In Chapter 3 we highlight the importance of the “water” in tariffs in tariff aggregation, and we provide an appropriate methodology taking advantage of a detailed database for Swiss domestic prices for beef products.

The third bias we cover is related to the model-endogenous determination of tariffs under TRQ. Conventional aggregation does not take into account that tariff rates change depending on the quota fill rate, which can lead to both an over or underestimation of the applied tariff rate. As a substantial proportion of agricultural production in developed countries is protected by TRQs (see for example de Gorter and Kliauga, 2006), the TRQ issue is especially relevant for agri-food markets, and therefore for the ex-ante impact assessment of trade liberalization scenarios on agriculture.

The two aggregators we propose deal with the above three aggregation biases to different extent, and following different approaches. For comparison reasons, we also implement and test a traditional (fixed weight) aggregator representing conventional approaches. In Table 1.1 we summarize the main features of the tariff aggregators discussed in Chapter 3.

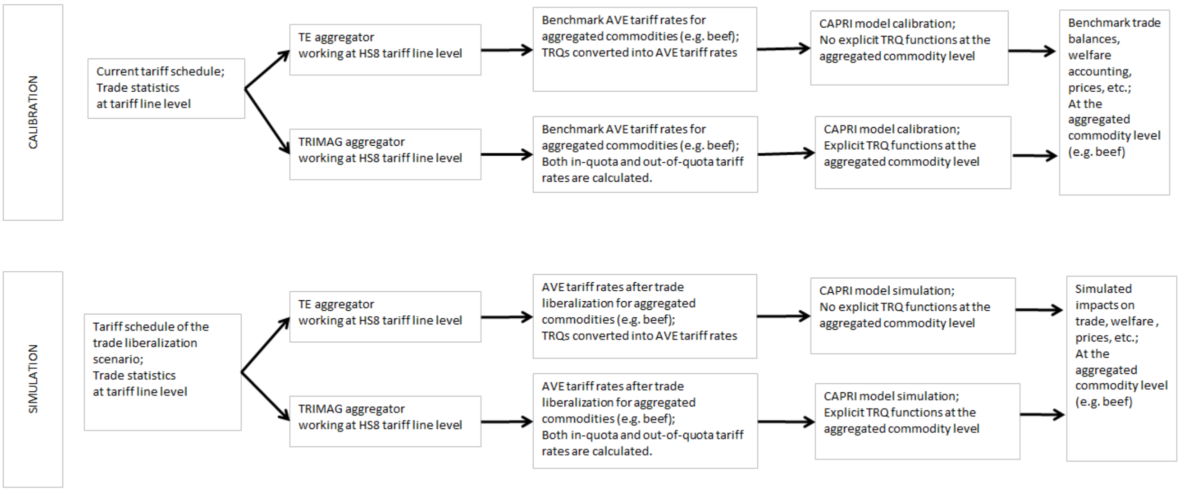
Table 1.1: Properties of tariff aggregators in respect to selected aggregation biases

	Traditional (fixed weight) aggregators	Trade Expenditure (TE) aggregator	TRIMAG aggregator
Substitution effect at the tariff line level	Not taken into account	via CES import demand system	via CES demand system for aggregation weights
Water in tariffs	Not taken into account	Not taken into account	Explicitly taken into account using a specific dataset on domestic and c.i.f. prices
Tariff Rate Quotas (TRQs)	via tariff equivalent; fix applied rate	via tariff equivalent; variable applied rate with explicit TRQ functions	Via TRQ function at aggregate level; calculates both aggregated in quota and out of quota rates

We assess the capabilities of the two proposed aggregators by analyzing Swiss tariff dismantling scenarios for beef imports. We follow a two-stage, comparative static approach that is typical in applied trade modelling ((Francois et al., 2005), (Philippidis and Sanjuán, 2007),(Egger et al., 2015)). Both the TE and TRIMAG aggregators are implemented as pre-model aggregation modules in the same large-scale global PE modelling framework of the Common Agricultural Policy Regionalized Impact (CAPRI) model (Britz and Witzke, 2015), which renders systematic direct comparison possible. Assuming different tariff dismantling scenarios for the EU beef exports to Switzerland, both pre- and post-reform aggregated tariffs are calculated with the TE and TRIMAG approaches. In order to evaluate the performance of the proposed aggregators in policy impact assessment, the aggregated tariffs are plugged into CAPRI and the economic impacts of the liberalization scenarios are simulated.

A more precise illustration of the modelling approach is presented on Figure 1.2. First current aggregated tariffs are calculated for CAPRI with the proposed aggregation modules: a single ad valorem equivalent tariff in the TE aggregator versus both in-quota and out-of-quota tariff rates in TRIMAG. Those tariffs then enter the calibration process of CAPRI that creates a baseline scenario which serves as the benchmark in the comparative analysis. Aggregated tariffs are also calculated for the trade liberalization scenarios, again with both proposed approaches. The aggregated tariffs (after liberalization) are then used in the CAPRI simulation providing the simulated impacts on trade (market balances and prices) and welfare at the aggregated commodity level for the different policy scenarios.

Figure 1.2: Extended modelling approach with pre-model tariff aggregation modules



The simulation results confirm the standard finding in literature that traditional (fixed weight) aggregators tend to lead to biased estimates for the gains from trade liberalization, both in terms of the impact on trade flows and welfare (Anderson, 2009,Laborde et al., 2017). We systematically compare simulated welfare and trade impacts derived both with traditional aggregation and with the proposed approaches. Systematic differences in the simulation results shed light on the importance of the investigated aggregation biases: substitution effects, "water" in the tariff lines and the variable tariff rates under TRQ regimes.

We complement the literature by finding that the difference between the fixed weight aggregator and those proposed to correct for important aggregation biases is particularly large when trade liberalization scenarios introduce large variation in tariff cuts. We therefore provide further empirical evidence that the use of fixed weight aggregators is not recommended in case of large heterogeneity (tariff dispersion) in tariffs structures. This is not only true when the variability of the initial tariffs is high, as already reported in the literature (e.g. (Laborde et al., 2017)), but also in case trade liberalization is expected to increase tariff dispersion to a large extent.

1.2.3 The interplay of trade and emission-mitigation policies

A large body of literature discusses emission leakage effects of unilateral greenhouse gas mitigation efforts, pointing to potentially significant impacts (e.g. Lee et al. 2007; Herrero et al. 2016; Pérez Dominguez et al. 2012, 2016; Van Doorslaer et al. 2015; Fellmann et al. 2017). Whether trade liberalization of agri-food markets potentially contributes to emission mitigation efforts or rather hinders it, is mainly an empirical question. Theoretical considerations alone cannot provide a decisive answer. The theoretical framework of environmental effects of trade-liberalization (Grossman and Krueger 1991) breaks down trade liberalization impacts on GHG emissions to (1) the scale effect, i.e. liberalized trade boosts total supply and consumption, thus ceteris paribus increasing global GHG emissions; (2) the composition effect, i.e. facilitating trade also changes the composition of the goods produced and consumed, with a net effect on global emissions depending on the relative emission efficiencies of the economic sectors; and (3) the technique effect, i.e. liberalizing trade speeds up technological development and technology transfer unequivocally leading to more emission-efficient technologies and therefore to a reduction in global emissions. The total net impact of trade liberalization on GHG mitigation depends on the relative weight of the above three components and therefore requires a thorough quantitative assessment. Existing empirical evidence on the net impact is controversial and reported between between two extremes: (i) trade liberalization and globalization leads to environmental degradation, especially in developing countries, and (ii) more liberalized trade leads to increased economic growth with positive spill-over effects on the environment (Copeland and Taylor 2004; Wiedmann et al. 2007; Peters and Hertwich 2008; Huang et al. 2011; Peters et al. 2011). The mixed existing empirical evidence on the net aggregated effect of trade on global emissions hints towards the case specificity of impacts.

In Chapter 4 we provide some empirical evidence on the contribution of trade liberalization to global greenhouse gas mitigation efforts in the context of the EU agriculture. With the mean of a comparative static analysis with the CAPRI modelling system, we investigate the interplay of the current EU trade agenda and a hypothetic EU-wide carbon tax for agriculture. Our aim is to highlight the challenges that the global context pose to EU mitigation efforts, and draw policy recommendations for more efficient future policy design which allows for increased contribution of agriculture to limiting global warming. At the same time, the potentially strong interrelationship between trade and emission mitigation policies further motivates our research for reviewing trade policy representations in AEMs.

The EU is actively seeking to engage in a number of regional FTAs with its important trading partners, as an alternative to the multilateral WTO negotiations that seem to be stalled in the last few years. The political driving force behind that strategy seems to be the objectives of the Juncker Commission and the attempts to boost economic growth with increasing trade. We focus on those EU trade deals that are already under negotiation or likely to be negotiated in the mid-term (Boulanger et al., 2016): (i) two recently concluded but not yet adapted FTAs with Canada and Vietnam; (ii) major ongoing trade negotiations with the USA, the Mercosur countries, Japan, Thailand, the Philippines and Indonesia; (iii) two FTAs with Australia and New-Zealand, which are to be initiated at the time of writing this thesis.

As concluded tariff schedules are not yet available for most of the FTAs we consider, we apply a simplified approach for trade policy representation. We introduce a uniform, and rather ambitious, tariff cut on agri-food products: full elimination of tariffs for most (non-sensitive) agricultural commodities and a 50% (partial) tariff cut for the rest of the products. The selection of sensitive products follows the approach of Boulanger et al. (2016), and it is based on expert judgment supplemented by a selection algorithm focusing on foregone tariff revenues.

For the analysis, we use the CAPRI (Common Agricultural Policy Regional Impact Analysis) modelling system (Britz and Witzke 2014). The standard CAPRI model version includes explicit Tariff Rate Quota (TRQ) functions. In order to implement our simplified tariff cut assumptions, however, we covnert TRQs into their ad-valorem equivalent (AVE) tariff rates. Representing TRQs with their AVE equivalent tariff rates enables us to simply cut them by a given percentage, without going into assumptions on possible quota expansions or changes in in-quota or out-of-quota tariff rates. The drawback of the simplified AVE representation is that simulated trade liberalization impacts might be overestimated. Even if increasing imports overshoot the quota threshold, this does not imply an immediate increase in tariff rates in the model (Himics and Britz 2016).

With regard to GHG accounting, CAPRI model-endogenously calculates agricultural GHG emissions for nitrous oxide and methane. The calculation of emissions, however, follows different approaches for the EU and for non-EU countries. While the emissions of EU agriculture are calculated directly based on the IPCC guidelines on a per activity basis in the CAPRI supply model, GHG emissions for the rest of the world are estimated on a commodity basis (i.e. per kg of product) in the market model of CAPRI. The emission calculation for the EU countries and regions is linked to the inputs and outputs of agricultural production activities, following the IPCC guidelines (IPCC 2006). Several specific technological (i.e. technical and management-based) GHG mitigation options for EU agriculture are considered, focusing on technological options that are already available or will likely be available at the simulation year 2030. Even if some technological options are already in use in EU agriculture (e.g. precision farming) there is a large potential to cover a larger part of EU farming activities (Table 1.2).

Non-EU emission intensities are based on historic emission inventories and production data from FAOSTAT. To incorporate also the possibility of emission intensity changes over time, trend functions are estimated for the emission intensities in the rest of the world using IPCC Tier 1 coefficients as prior information within a robust Bayesian estimation framework, combining data on production quantities and emission inventories from FAOSTAT (Jansson et al. 2010, 2014; Pérez Domínguez et al. 2016).

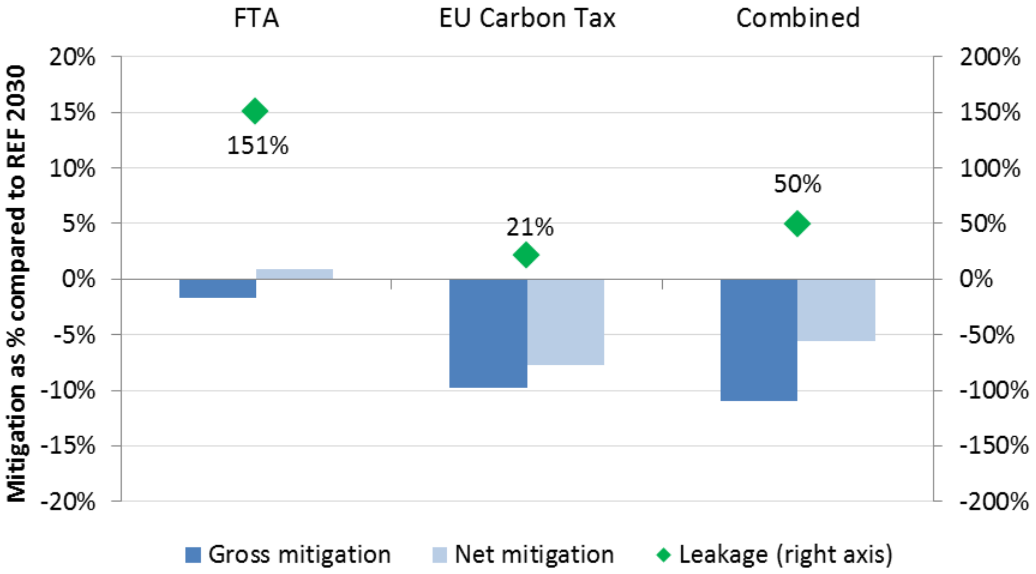
Table 1.2: Technological GHG mitigation options available for adoption by EU farmers

Sector	**Technological mitigation options**
Livestock	Anaerobic digestion at farm scale, Low nitrogen feed, Linseed as feed additive, Nitrate as feed additive, Vaccination against methanogenic bacteria in the rumen, and specific breeding programs to increase (i) milk yields of dairy cows and (ii) ruminant feed efficiency
Crops	Precision farming, Variable Rate Technology, Better timing of fertilization, Nitrification inhibitors, Rice measures, Fallowing histosols (organic soils), Increasing legume share on temporary grassland

In a comparative static analysis with CAPRI we compare three policy scenarios to a business as usual scenario (Reference): (i) a scenario that assumes an ambitious EU trade agenda to be fulfilled by 2030 (FTA scenario), (ii) a scenario for EU agriculture where a carbon tax of 50 EUR/t CO_2 equivalents is applied to non-CO_2 (i.e. methane and nitrous oxide) emissions of EU agricultural activities (EU Carbon Tax scenario), and (iii) a combination of the two. The three scenarios aim to break down the combined economic and environmental impacts of a simultaneous trade liberalization and emission reduction policy, and shed some light on the policy interactions.

One of our key results is that the EU trade liberalization agenda is likely to increase significantly the emission leakage effects. While emission leakage can already be observed in the EU Carbon Tax scenario (21%), combining it with trade liberalization further increases the leakage effect to 50% (Figure Figure 1.3). That significant leakage effect is due to the EU supply adjustment and the related increase of EU imports from relatively less emission-efficient countries. The sectoral and regional impacts are further analysed in Chapter 4.

Figure 1.3: EU emission mitigation and leakage as percentage of gross mitigation



As main policy recommendation we call the attention to the importance of cross negotiating FTAs with the design of National Determined Contributions (NDCs) to the Paris Agreement, assuring that mitigation efforts are not undermined in sectors where trade is expected to increase the most. Not going into a political economy discussion, taking into account global climate change objectives in FTA negotiations can be done in multiple ways. For example, depending on the relative emission efficiency in production systems, mitigation efforts in the FTA partners could be partly co-funded. There are also several border adjustment processes proposed in the literature to adjust for the carbon-load (and thus the differences in relative emission efficiencies) of agricultural commodity trade.

The agricultural sector is specifically subject to a multitude of sanitary and food safety regulations that often act as non-tariff barriers (NTMs) to trade. Most of the EU's current trade negotiations address NTMs with the aim of reducing them significantly. Although NTMs, and their potential reduction, might have significant impacts on the simulation results, we could not include them in our analysis, lacking an adequate database at the global scale with a detailed coverage of agri-food trade. In addition, Armington trade models, such as CAPRI, are not able to simulate emerging trade flows which flows are currently only marginal but which could become significant after trade liberalization. Both the absence of NTMs and the zero trade flow issue in our modelling framework imply a possible underestimation of the trade liberalization impacts (Philippidis et al., 2013, 2014). On the other hand, modelling the EU's trade agenda in isolation probably leads to an overestimation of the efficiency of EU trade liberalization, as countervailing regional FTAs, or a future WTO agreement would likely lower the EU gains from this liberalized trade agenda. It is therefore unclear whether our simulation results reflect somewhat magnified or underestimated trade liberalization impacts.

1.3 Conclusions and prospects for further research

This thesis revisits trade policy representations in applied trade modelling ranging from the fine level of details entailed in tariff line level data until more aggregated and more schematic policy representations often used for forward looking exploratory policy analysis. We start our investigation with the question, originally posed by (Ko and Britz, 2013), whether the geographic detail of trade and trade policy representation in AEMs induce a systematic bias in simulated trade liberalization impacts. Here we do not simply find further evidence that such a bias exists, but we develop a welfare consistent method that is invariant to that bias, i.e. invariant to the geographical details regarding the exporter countries. In other words, we show how to collapse disaggregated model structures to more aggregated ones without altering the simulated welfare impacts. On the way to develop our aggregation framework we make further contributions to the literature by integrating TRQs in the welfare-consistent aggregation framework of (Bach and Martin, 2001) and (Anderson, 2009), and by critically accessing the assumption of fix domestic supply applied by these authors.

The proposed welfare consistent aggregation is illustrated and tested by developing a PE model for the South-Korean dairy market and simulating the EU-South Korea FTA with that model. The simulation results highlight an important issue related to consistent aggregators: they do not necessarily reduce aggregation bias in all key simulated outcomes of economic analysis. On the contrary, the bias typically increases (can we support it with examples from the paper?). Therefore we turn our research focus in Chapter 3 towards developing multi-purpose aggregators, i.e. aggregators that improve on a multitude of common aggregation biases, such as substitution effects in imported consumption bundles at the tariff line, "water" in tariffs and model-endogenous tariff rates under TRQ regimes. Our multi-purpose aggregation framework borrows ideas from the consistent aggregator literature and introduces explicitly modelled import demand systems (of the CES form) into the calculation of aggregated tariff rates. Either using an implicit function approach for the aggregator function (as in the case of the proposed TE aggregator), or adjusting aggregation weights in a more traditional weighted approach (TRIMAG).

The proposed improvements for tariff aggregation in Chapter 2 and 3 require, and make use of, detailed information on trade policies and trade statistics at the fine level of tariff lines[1]. For future trade policies, e.g. those that are currently negotiated, such a detail is not available for trade modellers. Therefore we move from modelling very specific policy scenarios with AEMs extended to the tariff line to applying simpler policy representations based on ad-valorem equivalent tariff rates. That latter approach is more suitable for assessing the impacts of still uncertain trade agreements due to the data limitations. More precisely we focus on the research field dealing with the impacts of future trade policies on global GHG mitigation efforts in agriculture. Complementing a large body of literature on the impact of FTAs on global climate change mitigation, we find empirical evidence that the EU's current trade agenda might jeopardize future climate action in EU agriculture. That finding is mainly driven by the significant simulated emission leakage impacts, and hinges on the key assumptions that the EU's climate mitigation efforts are unilateral (not embedded in a coordinated global effort for reducing agricultural emissions), the EU farming sector is relatively emission efficient and that other FTAs excluding the EU do not countervail the trade implications of the EU trade agenda. That empirical finding further motivates the need for improved and tailor-made trade policy representation in AEMs, as trade policy representation has a crucial impact on simulated emission leakage impacts which might become major impediments of global greenhouse-gas mitigation policies in agriculture. As long as trade policies have significant impacts on international

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[1] In the empirical examples of Chapter 2 and Chapter 3, data at the 6 and 8 digit levels of the Harmonized System of tariff nomenclature are used.

trade (the transmitter of emission leakage effects between countries), improving trade modelling will also improve the assessment of emission mitigation efforts at the global scale.

Tariff and Tariff Rate Quota aggregation is an overarching issue in the thesis, with a focus on the aggregation bias in several simulation outcomes of AEMs. The tariff aggregation techniques we develop and present in the thesis are always adjusted to the specific needs of the policy analysis at hand, and we put an emphasis on illustrating the aggregation techniques by empirical examples. Regarding the practical implementation of the proposed methodological approaches in existing trade models, we aim at methodological approaches which can be implemented even in large-scale numerical simulation models with relatively low efforts, not increasing significantly the complexity of existing model structures and databases. All trade policy representation approaches in the thesis, including both the tariff line level aggregation methods and the more general ad-valorem representation, can therefore be implemented as pre-model aggregation modules, loosely linked to existing models. The pre-model implementation decreases the necessary efforts for practitioners to adopt the proposed (improved) policy representations in their modelling systems. In that sense the thesis provides practical implementation schemes for trade modellers to extend their existing models with limited efforts and make better use of detailed tariff and trade information at the tariff line level.

After the Uruguay Round of negotiations and a number of subsequent regional trade agreements significantly lowered tariff protection globally, modern FTAs focus less on tariff reductions and more on non-tariff measures (NTM). The regional extension of the Anderson aggregation framework, described in Chapter 2, can in theory applied also to NTMs, as far as those NTMs can be reasonably well modelled as additional trade costs[2]. The extension of our aggregation approach to NTMs is one possible avenue for further research. Unfortunately, data availability seriously limits the practical extension of our tariff line level approaches to cover NTMs. Despite the current efforts to develop harmonized and global databases for NTMs (e.g. UNCTAD 2017), a global NTM database of use for practical trade modelling at the tariff line is still unavailable. Building such databases would also require a tremendous econometric estimation work, probably based on the new developments and current efforts in the gravity model literature (see e.g. Cadot and Gourdon, 2016; Kee et al., 2011, 2009; Niu et al., 2018).

Both the proposed welfare consistent aggregator of Chapter 2 and the multipurpose aggregators of Chapter 3 are tested in the partial equilibrium setting, imposing certain limitations on (within economy) monetary transfers, income effects in the import demand systems, the lack of cross-sectoral impacts etc. Further empirical assessment and methodological adjustments are needed to explore the performance of the proposed aggregators in a general equilibrium setup and in more complex model structures, such as Computable General Equilibrium (CGE) models of the whole economy. The scope of the scenarios we used for testing the proposed tariff aggregators are somewhat limited in scope, and focus on one specific sector at a time (dairy sector in case of the EU-South Korea FTA and on the beef sector in the Swiss tariff dismantling scenarios). Increasing the complexity of the scenarios and evaluate cross-sectoral effects therefore seems a natural direction

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[22] Modelling NTMs as additional trade costs (e.g. representing them by additional tariffs at the border) is only one of many possibilities. In CGE modelling practice NTMs are often modelled using sand-in-the-wheel (productivity-based) or other supply side techniques. The appropriate choice of the modelling approach depends both on the fine details of the NTM measure itself as well as on data availability.

for further improving the proposed aggregation approaches. An area for possible further research is therefore testing the proposed tariff aggregators in CGE models and for scenarios covering global trade reforms. Evaluating the possible reduction in the aggregation bias in simulated results would fit the strand of literature testing advanced tariff aggregation in CGE models (e.g. Laborde et al., 2017).

In Chapter 4 we highlighted the potentially significant emission leakage impacts linked to the EU trade liberalization agenda. The simulated impacts, however, crucially depend on the relative emission efficiency of the EU and its trading partners. The emission efficiency of the agriculture in non-EU countries are represented by emission coefficients in our modelling approach, based on a commodity based emission accounting, and taking into account past trends for the emissions of agricultural sectors. Still, improving the estimation of those emission coefficients, and developing scenarios on possible future adjustments in emission coefficients worldwide, is an important area for future research. That would allow us to better assess the role of technological development for restricting emission leakage and for limiting global warming.

1.4 References

Anderson, J.E., 2009. Consistent Trade Policy Aggregation*. Int. Econ. Rev. 50, 903–927. doi:10.1111/j.1468-2354.2009.00553.x

Anderson, J.E., Neary, J.P., 1994. Measuring the Restrictiveness of Trade Policy. World Bank Econ. Rev. 8, 151–169. doi:10.1093/wber/8.2.151

Bach, C.F., Martin, W., 2001. Would the right tariff aggregator for policy analysis please stand up? J. Policy Model. 23, 621–635. doi:10.1016/S0161-8938(01)00077-1

Boulanger, P., Dudu, H., Ferrari, E., Himics, M., M'Barek, R. (2016): Cumulative economic impact of future trade agreements on EU agriculture. JRC Science for Policy Report, European Commission, Luxembourg: Publications Office of the European Union. http://dx.doi.org/10.2788/194880.

Bchir, M.H., Jean, S., Laborde, D., 2006. Binding Overhang and Tariff-Cutting Formulas. Rev. World Econ. Weltwirtschaftliches Arch. 142, 207–232.

Britz, W., Leip, A., 2009. Development of marginal emission factors for N losses from agricultural soils with the DNDC–CAPRI meta-model. React. Nitrogen Agroecosystems Integr. Greenh. Gas Interact. 133, 267–279. doi:10.1016/j.agee.2009.04.026

Britz, W., van der Mensbrugghe, D., 2016. Reducing unwanted consequences of aggregation in large-scale economic models - A systematic empirical evaluation with the GTAP model. Econ. Model. 59, 463–472. doi:10.1016/j.econmod.2016.07.021

Britz, W., Witzke, P. (Eds.), 2015. CAPRI model documentation 2014.

Cadot, O., Gourdon, J., 2016. Non-tariff measures, preferential trade agreements, and prices: new evidence. Rev. World Econ. 152, 227–249. doi:10.1007/s10290-015-0242-9

Cipollina, M., Salvatici, L., 2008. Measuring Protection: Mission Impossible? J. Econ. Surv. 22, 577–616. doi:10.1111/j.1467-6419.2007.00543.x

Copeland B.R., Scott Taylor, M. (2004): Trade, Growth, and the Environment. Journal of Economic Literature, 42 (1): 7-71.

de Gorter, H. and Kliauga, E. (2006). Reducing tariffs versus expanding tariff rate quotas. In Anderson, K, and Martin, W. (eds). Agricultural Trade Reform and the Doha Development Agenda. Basingstoke, U.K.: Palgrave Macmillan; Washington, DC: World Bank.

Deaton, A., Muellbauer, J., 1980. Economics and consumer behavior. Cambridge University Press, Cambridge.

Egger, P., Francois, J., Manchin, M., Nelson, D., 2015. Non-tariff barriers, integration and the transatlantic economy. Econ. Policy 30, 539–584. doi:10.1093/epolic/eiv008

European Commission, 2017. The future of food and farming. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. (COM (2017)713). Brussels.

European Union (2018) The Juncker Commission's ten priorities State of play in early 2018. doi:10.2861/501774

Fellmann, T., P. Witzke, F. Weiss, B. Van Doorslaer, D. Drabik, I. Huck, G. Salputra, T. Jansson, A. Leip (2017): Major challenges of integrating agriculture into climate change mitigation policy frameworks. Mitigation and Adaptation Strategies for Global Change. http://dx.doi.org/10.1007/s11027-017-9743-2.

Francois, J., Van Meijl, H., Van Tongeren, F., 2005. Trade liberalization in the Doha Development Round. Econ. Policy 20, 349–391. doi:10.1111/j.1468-0327.2005.00141.x

Grant, J.H., Hertel, T.W., Rutherford, T.F., 2007. Tariff line analysis of U.S. and international dairy protection. Agric. Econ. 37, 271–280. doi:10.1111/j.1574-0862.2007.00251.x

Grossman, G.M., Krueger, A.B. (1991): Environmental impacts of a North American Free Trade Agreement. National Bureau of Economic Research Working Paper 3914.

Guimbard, H., Jean, S., Mimouni, M., Pichot, X., 2012. MAcMap-HS6 2007, An exhaustive and consistent measure of applied protection in 2007. Int. Econ. 130, 99–121. doi:10.1016/S2110-7017(13)60046-3

Henning, S., Pierre, G., Tom, W., Vincent, C., Mauricio, R., Cees, de H., 2006. Livestock's long shadow: Environmental issues and options. FAO, Rome.

Herrero, M., B. Henderson, P. Havlík, P.K. Thornton, R.T. Conant, P. Smith, S. Wirsenius, A.N. Hristov, P. Gerber, M. Gill, K. Butterbach-Bahl, H. Valin, T. Garnett, E. Stehfest (2016): Greenhouse gas mitigation potentials in the livestock sector. Nature Climate Change 6, 452–461.

Huang, H., M. von Lampe, F. van Tongeren (2011): Climate change and trade in agriculture. Food Policy 36, S9-S13.

IPCC (2006): 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Prepared by the National Greenhouse Gas Inventories Programme. Eggleston HAS., Biennia L., Miwa K., Negara T. and Tanabe K. (eds). Published: IGES, Japan.

Jansson, T., Perez Domínguez, I., Weiss, F. (2010): Estimation of Greenhouse Gas coefficients per commodity and world region to capture emission leakage in European Agriculture. Paper presented at the 119th EAAE seminar "Sustainability in the Food Sector", Capri, Italy.

Jansson, T. Pérez Domínguez I. (2014): Greenhouse gas emission coefficients per commodity estimated globally using Aglink-Cosimo and FAOSTAT data and IPCC methods, OECD internal document.

Kee, H.L., Neagu, C., Nicita, A., 2011. Is Protectionism on the Rise? Assessing National Trade Policies during the Crisis of 2008. Rev. Econ. Stat. 95, 342–346. doi:10.1162/REST_a_00241

Kee, H.L., Nicita, A., Olarreaga, M., 2009. Estimating Trade Restrictiveness Indices*. Econ. J. 119, 172–199. doi:10.1111/j.1468-0297.2008.02209.x

Ko, J.-H., Britz, W., 2013. Does Regional and Sectoral Aggregation Matter? Sensitivity Analysis in the Context of an EU-South Korea FTA, in: Presented at the 16th Annual Conference on Global Economic Analysis, Shanghai, China. Presented at the Presented at the 16th Annual Conference on Global Economic Analysis, Shanghai, China.

Laborde, D., Martin, W., van der Mensbrugghe, D., 2017. Measuring the Impacts of Global Trade Reform with Optimal Aggregators of Distortions. Rev. Int. Econ. 25, 403–425. doi:10.1111/roie.12271

Lee, H.C., B.A. McCarl, U.A. Schneider, C.C. Chen (2007): Leakage and Comparative Advantage Implications of Agricultural Participation in Greenhouse Gas Emission Mitigation. Mitigation and Adaptation Strategies for Global Change 12(4), 471–494.

Narayanan, B.G., Hertel, T.W., Horridge, J.M., 2010. Disaggregated data and trade policy analysis: The value of linking partial and general equilibrium models. Econ. Model. 27, 755–766. doi:10.1016/j.econmod.2010.01.018

Niu, Z., Liu, C., Gunessee, S., Milner, C., 2018. Non-tariff and overall protection: evidence across countries and over time. Rev. World Econ. doi:10.1007/s10290-018-0317-5

Pelikan, J., Brockmeier, M., 2008. Im Dschungel der Importzoelle - Die Bedeutung der verwendeten Methodik bei der Aggregation von Importzoellen. Agrarwirtschaft 57, 119–129.

Pérez Domínguez, I., T. Fellmann, H.P. Witzke, T. Jansson, D. Oudendag, A. Gocht, D. Verhoog (2012): Agricultural GHG emissions in the EU: An Exploratory Economic Assessment of Mitigation Policy Options. JRC Scientific and Policy Reports, European Commission, Seville, http://doi.org/10.2791/8124.

Pérez Domínguez, I., T. Fellmann, F. Weiss, P. Witzke, J. Barreiro-Hurle, M. Himics, T. Jansson, G. Salputra, A. Leip (2016): An economic assessment of GHG mitigation policy options for EU agriculture (EcAMPA 2). JRC Science for Policy Report, European Commission, Luxembourg: Publications Office of the European Union. http://doi.org/10.2791/843461.

Peters, G.P., E.G. Hertwich (2008): CO2 embodied in international trade with implications for global climate policy. Environmental Science & Technology 42(5), 1401–1407.

Peters, G.P., J.C. Minx, C.L. Weber, O. Edenhofer (2011): Growth in emission transfers via international trade from 1990 to 2008. Proceedings of the National Academy of Sciences of the United States of America 108 (21), 8903–8908.

Philippidis, G., Sanjuán, A.I., 2007. An Analysis of Mercosur's Regional Trading Arrangements. World Econ. 30, 504–531. doi:10.1111/j.1467-9701.2007.01002.x

Philippidis, G., Resano-Ezcaray, H., Sanjuán-López, A.I. (2013): Capturing zero-trade values in gravity equations of trade: an analysis of protectionism in agro-food sectors. Agricultural Economics 44, 141–159. https://doi.org/10.1111/agec.12000

Philippidis, G., Resano, H., Sanjuán, A.I. (2014): Shifting Armington trade preferences: A re-examination of the Mercosur–EU negotiations. Economic Modelling 40, 21–32. https://doi.org/10.1016/j.econmod.2014.03.016

UNCTAD (2017a). UNCTAD TRAINS: The global database on non-tariff measures, version 2.0 2016. Preliminary version. United Nations, New York and Geneva.

Van Doorslaer, B, P. Witzke, I. Huck, F. Weiss, T. Fellmann, G. Salputra, T. Jansson, D. Drabik, A. Leip (2015): An economic assessment of GHG mitigation policy options for EU agriculture (EcAMPA). JRC Technical Reports, European Commission, Luxembourg: Publications Office of the European Union. http://dx.doi.org/10.2791/180800.

Wiedmann, T., Lenzen, M., Turner, K., Barrett, J. (2007): Examining the global environmental impact of regional consumption activities - Part 2: Review of input-output models for the assessment of environmental impacts embodied in trade. Ecological Economics 61, 15–26.

Chapter 2: Flexible and welfare-consistent tariff aggregation over exporter regions[3]

Abstract

In this paper we improve on existing tariff aggregation techniques in applied equilibrium models (AEM) with the aim of correcting for two sources of bias in simulated welfare results: (1) aggregation over exporter regions with significant tariff dispersion and (2) variable tariff rates determined by Tariff Rate Quota (TRQ) regimes. Both aspects seem important due to an increasing number of bilateral FTAs which drive up tariff divergence across countries and tend to apply TRQs, at least temporarily. We demonstrate that the proposed aggregation technique can handle both tariff and non-tariff barriers to trade by combining a number of tariff indexes in a modified trade balance condition in a welfare-consistent manner. Additionally, different rent-allocation shares for TRQs can be easily introduced in our methodological extension. We also address the implications of some rather strict behavioral assumptions with regard to demand that welfare consistent aggregation requires. An empirical analysis of the Korean dairy market in the EU-South Korea FTA using the proposed method shows that simulated welfare gains are largely affected by the tariff aggregation technique over regions and trade policy instruments. Based on this finding we recommend the more widespread application of welfare consistent tariff aggregation in applied modeling and further research on that topic.

Keywords: tariff aggregation; welfare consistent aggregation; flexible regional aggregation; Tariff Rate Quotas; EU-South Korea FTA; trade policy

JEL classification: F13, D58, Q17

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2.1 Introduction

Data on trade flows and tariffs are typically available at the detailed level of tariff lines (Guimbard et al., 2012), but not on supply and consumption. Aggregating trade flows and tariffs is therefore inevitable in empirical models of international trade. The still widely used trade weighted average tariffs are however not grounded in economic theory and suffer from endogeneity bias as higher tariffs decrease imports and thus aggregation weights. As a result, they systematically underestimate tariff protection at aggregate level, cf. Pelikan and Brockmeier (2008). Less known and only recently explored, however, is that simulated impacts with AEMs can be magnified simply by more regional detail. Subsequent chapters show that conventional tariff aggregation cannot consistently handle tariff dispersion over exporter countries, provoking that magnifying effect. We hence propose an alternative (flexible) aggregation technique that is both invariant to the geographical details of exporter countries and fully corrects for the associated bias.

The current practice of aggregating and using trade and policy data in AEM typically consists of three steps. The first one aggregates to the level of a standard set of (already highly aggregated) commodities, while regional detail is (almost) maintained, e.g. the widely used GTAP 8 database (Narayanan et al., 2012) comprises 57 sectors. The resulting bi-lateral datasets – in the case of the GTAP Version 8 comprising about 1.2 Mio trade flows and related policy instruments – are then distributed to the end users. In a second step, users aggregate these data further, including trade flows and tariffs, to arrive at their desired sectoral and regional detail, typically with aggregation tools specific to and distributed with the database. In the final step, the aggregated data are used in an equilibrium model to simulate scenario impacts. Unfortunately, the conventional aggregation methods have an unwanted side-effect on simulated welfare and trade impacts: these can be increased simply by choosing more regional detail (Ko and Britz, 2013). This paper thus aims at developing an aggregation method that is invariant to the geographical detail chosen for exporting countries.

Anderson and Neary (1994) pioneered tariff aggregation methods consistent with a selected measure of economic activity. Their Trade Restrictiveness Index (TRI), for example, is a compensating variation measure of welfare changes defined over the country's balance of trade (Martin, 1997). The TRI can be converted into a uniform ad valorem tariff rate that provokes the same welfare impact as the individual tariff line rates.

Unfortunately, one uniform tariff rate is not suitable in the general equilibrium framework as just one aggregator cannot resolve the tension between the marginal impact of tariff changes on tariff revenues and consumer expenditures. Bach and Martin (2001) therefore define separate aggregators for the expenditure and the tariff revenue function. Anderson (2009) simplifies their approach by plugging in an optimal combination of a trade weighted aggregator and what he calls the True Average Tariff (TAT) into the trade balance condition such that the computation does not require a complete equilibrium model at the tariff line level. Section 2.2.1 provides a review of that strand of literature.

Other approaches represent trade policies at the tariff line level and thus avoid tariff aggregation completely, but require model extensions. Grant et al. (2007) link a satellite partial equilibrium (PE) model of the global dairy markets at the tariff line level iteratively to the general equilibrium (GE) structure of Global Trade Analysis Project (GTAP, Hertel 1992). Also in the GTAP framework, Narayanan et al. (2010) investigates the impact of tariff liberalization on the Indian auto industry with a nested PE-GE approach. Unfortunately, neither the nested PE-GE approach nor the iterative model link scale up well, i.e. it is numerically difficult to extend them to all commodity markets or industries covered by the aggregate model.

Brockmeier and Bektasoglu (2014) compare the bias in simulation results caused by aggregation to those implied by different model structures (PE or GE framework) in linked modeling systems and find greater bias due to aggregation. Accordingly, McCleery and DePaolis (2014) see sectoral detail as highly important when building a trade model, but note that data availability typically prevents the desired level of disaggregation. Therefore the improvement of available tools for regional and sectoral aggregation, what this paper aims for, is of great relevance for applied research.

Our extension of the Anderson approach, which enables aggregating trade policies consistently over exporter regions, seems especially relevant for analyzing preferential and regional trade agreements (see section 2.2.2). In contrast, previous applications of tariff aggregates focused on overall trade restrictiveness in the face of unilateral (Anderson, 2009) or multilateral trade liberalization (Bureau and Salvatici, 2004, Manole and Martin, 2005 or Laborde et al. 2011). Our extended approach allows for flexible regional aggregation where so far aggregation tools such as GTAPAgg for global Social Accounting Matrices (Horridge, 2008) or TASTE for tariff data bases (Horridge and Laborde, 2008) apply trade weighted averages subject to potential inconsistent welfare results.

Furthermore, we show in section 2.2.3 how to include based on a Mixed Complementarity Problem (Rutherford, 1995) approach the per unit quota rent of (bilateral) TRQs via a shadow tariff in the aggregation framework. Despite that fact that Anderson (2009) already discussed the techniques to handle import quotas, his optimal combination of tariff aggregators has not yet been adapted in the literature to a case where TRQs are explicitly modeled.

Finally, we aim at making welfare consistent tariff aggregation more accessible to policy analysts and Computable General Equilibrium (CGE) modelers. In order to do so, we present the technique in the context of those import demand systems typically available in larger-scale AEMs. To give an applied perspective to the theoretical framework, the numerical example of Bach and Martin (2001, page 630-632) is replicated and further extended in section 2.3.1. We point out to a series of implicit assumptions in the Bach and Martin paper that have serious impacts on the aggregated tariffs. Some of these assumptions are later relaxed or modified in order to derive more intuitive simulation response in trade liberalization scenarios.

In section 2.3.2 we apply the extended approach to the more complex example of the Korean dairy market under the EU-South Korea Free Trade Agreement (FTA), with both tariff reductions and TRQ expansions. Tariff aggregators are estimated and compared for Korean dairy imports from the EU at different stages of the FTA implementation and geographical resolutions for the EU. These estimates are specific to the main European exporter countries of dairy products to Korea. Section 2.4 concludes with a short summary and with some general remarks on using these tariff aggregators in applied modeling work.

We refrain from a full-fledged large-scale modeling exercise. Instead, we keep our focus solely on the aggregation issue and define the scope of our empirical model strictly within the framework of an import demand system that is shared across the AEM community and use as a common tool for tariff aggregation. We believe that restricting the discussion to a smaller part of larger modeling systems and their application is a worthwhile simplification and helps disentangle the impacts of regional aggregation from the numerous (but here non-relevant) cross-effects prevalent in large-scale AEMs (sectoral breakdown, representation of demand and supply, closure rules just to name a few). We nevertheless perform a robustness-check based on sensitivity analysis of key model parameters, such as substitution elasticities and parameters related to the rent allocation.

2.2 Methodology for consistent aggregators of trade policies

This section is a formal introduction to the welfare consistent tariff aggregators for the general equilibrium framework, and to the extensions we propose. It is organized as follows. Section 2.2.1 describes the state-of-the-art by introducing Anderson's (2009) optimal combination of tariff aggregators. Section 2.2.2 introduces an explicit regional dimension in the standard framework in order to deal with tariff dispersion over exporter regions. Section 2.2.3 further extends the methodology by defining consistent aggregators for tariffs under TRQs.

2.2.1 Standard welfare-consistent aggregators

While Bach and Martin (Bach and Martin, 2001) first called attention to the problem of welfare consistent tariff aggregation in the general equilibrium framework, our discussion below builds mostly on the subsequent work of Anderson (Anderson, 2009), using his notations and terms, and refers back to the original Bach-Martin approach only to highlight differences. These tariff aggregation techniques aim at deriving uniform tariffs that are optimal in the sense that they yield the same welfare result as the detailed tariff structure would do. Structure, parameterization and input data of the underlying model all have an impact on the derived aggregated tariffs.

Let us consider a small open economy, where a subset of tradable goods is to be aggregated. The vector of domestic prices is partitioned to (p,π), where p and π denotes the price vector of products to be aggregated and other tradables, respectively. Trade policies[4] wedge domestic prices away from constant world prices $(\bar{p}^w,\bar{\pi}^w)$. The difference between the consumers' expenditure function and the gross domestic product (GDP) function defines the trade balance equilibrium condition for the economy:

$$E(p,\pi,u)=e(p,\pi,u)-g(p,\pi)$$

where u denotes real income. The excess demand functions can be derived by Shephard's and Hotelling's Lemmas respectively: $E_p=e_p-g_p$ and $E_\pi=e_\pi-g_\pi$ (the subscripts denote partial derivatives).

The balance of trade condition then guarantees that the value of imports is equal to the value of exports plus a possible financial inflow b:

$$B(p,\pi,u,\bar{p}^w,\bar{\pi}^w)=E(p,\pi,u)-(p-\bar{p}^w)'E_p-(\pi-\bar{\pi}^w)'E_\pi-b=0. \quad (2.1)$$

By fixing real GDP, the function B above (termed the balance of trade function) provides a compensation variation measure of welfare changes (Martin, 1997). The TRI index (Anderson and

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[4] For the sake of simplicity, we only consider tariffs as a cause for the price wedges in this theoretical discussion. Accordingly, we refer to the aggregation of trade policy instruments as tariff aggregation.

Neary, 2005) is based exactly on this welfare measure and equal to the uniform tariff factor denoted by $1+\tau^{\Delta}$ that would aggregate the single tariffs without altering the balance of trade:

$$\tau^{\Delta}\ :\ B((1+\tau^{\Delta})\bar{p}^{w},\pi,\bar{u},\bar{p}^{w},\bar{\pi}^{w})=B(p,\pi,\bar{u},\bar{p}^{w},\bar{\pi}^{w}).$$

Consistent aggregation with regard to the balance of trade function requires further restrictions both on the supply and demand sides of the economy. We assume (weakly) separable demand for the product group with price vector p and assume that the group enters consumer preferences homothetically. Separable homotheticity implies two-stage budgeting and allows to define price indexes over product groups entering the top level of the consumers' budget allocation problem (Deaton and Muellbauer, 1980).

That type of consistent aggregation excludes relative price changes on the supply side in the commodity group being aggregated. A sufficient condition for that restriction is that supply prices (the world price vector p^{w}) are independent of trade policies, satisfied in the small country case. Even weaker supply side separability assumptions can make consistent aggregation possible, as discussed by (Anderson, 2009).

While the TRI index reproduces the balance of trade, it cannot get both the trade volumes and the tariff revenues right (Anderson, 2009). Bach and Martin (2001) therefore suggest two different aggregators in equation (2.1): one for the trade expenditure $\left(T^{exp}\right)$ and one for the tariff revenue part $\left(T^{trev}\right)$. Taking advantage of separable homotheticity, we can construct an aggregator for the expenditure part as an implicit function of the domestic price vector[5]:

$$\phi:\mathbb{R}^{n}\rightarrow\mathbb{R}\mid E(\phi(p),\pi,\bar{u},\bar{p}^{w},\bar{\pi}^{w})=E(p,\pi,\bar{u},\bar{p}^{w},\bar{\pi}^{w}). \quad (2.2)$$

The True Average Tariff (Anderson, 2009) can then be introduced as the aggregated price wedge relative to the aggregate domestic price:

$$T^{\delta}=\frac{\phi(p)-\phi(\bar{p}^{w})}{\phi(p)}=1-\frac{\phi(\bar{p}^{w})}{\phi(p)}. \quad (2.3)$$

The TAT is conceptually equivalent to the Bach and Martin trade expenditure aggregator. The latter, however, measures the aggregate price wedge relative to an average world price. In fact, if the $\bar{p}^{w}$ world prices are uniform then the following relationship holds between the two aggregators:

$$T^{exp}=\frac{\phi(p)-\phi(\bar{p}^{w})}{\phi(\bar{p}^{w})}=\frac{\phi(p)}{\phi(\bar{p}^{w})}-1=\frac{1}{1-T^{\delta}}-1. \quad (2.4)$$

Under specific restrictions, it is possible to derive a closed-form solution for $T^{\exp}$ (see Manole and Martin, 2005). Here we focus on setting up a modeling framework to numerically derive the tariff aggregators, and so for our purposes the above implicit formula is satisfactory.

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[5] Note that ϕ inherits the homogeneity property of the expenditure function.

Following Anderson, we define the second aggregator for the tariff revenue part as a combination of T^{δ} and the simple trade weighted average tariff. The latter is calculated as:

$$T^{a} = \sum_{j} w_j T_j, \quad (2.5)$$

where the index j runs over the imported goods with price vector p, $w_j = p_j E_{p_j} / (\sum_j p_j E_{p_j})$ denote value shares and $T_j = (p_j - \bar{p}_j^{\,w}) / p_j$ are the single tariff rates relative to the domestic prices. The expression for tariff revenues then can be substituted with an optimal combination of (T^{δ}, T^{a}) in equation (2.1):

$$E(\frac{\phi(\bar{p}^{w})}{1-T^{\delta}}, \pi, u) - T^{a} E_{\phi} \frac{\phi(\bar{p}^{w})}{1-T^{\delta}} - (\pi - \bar{\pi}^{w})' E_{\pi} - b = 0. \quad (2.6)$$

The above aggregation is consistent with respect to the domestic expenditure on imports (by definition, see the first term) and also guarantees that the aggregation does not alter welfare (the balance of trade remains unchanged). Obviously, that also implies consistency with respect to tariff revenues as the difference between the trade balance and trade expenditures.

2.2.2 Introducing a regional dimension for the tariff aggregators

In the following section we introduce an explicit regional dimension in the above framework by splitting up the exporter country into sub-regions. As a result, imported goods are differentiated both by tariff line and by place of origin. First we define sub-region-specific aggregator functions analogue to equation (2.2):

$$(\varphi_1, \dots, \varphi_n) : \mathbb{R}^{n \times m} \to \mathbb{R}^{n} \mid E((\varphi_i(p))_{i=1}^{n}, \pi, u) = E(p, \pi, u), \quad (2.7)$$

where the i subscript runs over the exporter regions and the number of imported product types (number of tariff lines) is m. Exporter specific versions of the True Average Tariff rates can then simply be calculated as:

$$T_i^{\delta} = 1 - \frac{\varphi_i(\bar{p}^{w})}{\varphi_i(p)}, \quad \forall i \in \{1, \dots, n\}. \quad (2.8)$$

Unfortunately, there are more variables than equations in the equation system of (2.7) such that no unique solution exists, in general. In the separable homothetic case, however, equation (2.7) reduces to a problem where the aggregators are calculated based on their impact on the composite price index:

$$(\varphi_1, \dots, \varphi_n) : \mathbb{R}^{n \times m} \to \mathbb{R}^{n} \mid p_c((\varphi_i(p))_{i=1}^{n}, \pi) = p_c(p, \pi), \quad (2.9)$$

simply because in this case $E(p, \pi, u) = p_c(p, \pi) u$, where p_c denotes the composite price index.

In particular, it is possible to derive the regional aggregators for each region independently:

$$(\hat{\varphi}_1, \dots, \hat{\varphi}_n) : \mathbb{R}^{n \times m} \to \mathbb{R} \mid p_c(\hat{\varphi}_i(p), p^{-i}, \pi) = p_c(p, \pi), \ \forall i \in \{1, \dots, n\}, \quad (2.10)$$

where p^{-i} denotes domestic prices of all imported commodities other than exported by region i. The advantage of the formulation in equation (2.10) is that the regional aggregators $(\hat{\varphi}_i)_{i=1}^n$, and therefore the regional True Average Tariffs T_i^δ, can be computed in a sequence, rather than solving for them simultaneously. Sequential calculation greatly reduces numerical complexity. Appendix A provides a formal proof for the equivalence of simultaneous and sequential approaches.

The second aggregator for the trade weighted averages only needs to be extended with an additional regional dimension in order to arrive at exporter specific ones:

$$T_i^a = \sum_{j=1}^m w_{i,j} T_{i,j}, \ \forall i \in \{1,\ldots,n\},$$

where j runs over the index set of commodities. The single tariff rates relative to the domestic prices are calculated as $T_{i,j} = (p_{i,j} - \bar{p}_{i,j}^w)/p_{i,j}$, and the value shares take the form:

$$w_{i,j} = \frac{p_{i.j} E_{p_{i,j}}}{\sum_{k=1}^m p_{i,\mathrm{k}} E_{p_{i,\mathrm{k}}}}, \ \forall i, j.$$

Using the inherited homogeneity property of φ_i, $(i = 1\ldots n)$ the optimal combination of (T^δ, T^a) can be broken down[6] to a sum of regional combinations $(T_i^\delta, T_i^a)_{i=1}^n$:

$$T^a E_\phi \frac{\phi(\bar{p}^w)}{1-T^\delta} = \sum_i T_i^a E_{\phi_i} \frac{\varphi_i(\bar{p}^w)}{1-T_i^\delta}.$$

The above expression leads to the regional version of the balance of trade condition:

$$E\left[\frac{\varphi_1(\bar{p}^w)}{1-T_1^\delta}, \ldots, \frac{\varphi_n(\bar{p}^w)}{1-T_n^\delta}, \pi, u\right] - \sum_i T_i^a E_{\phi_i} \frac{\varphi_i(\bar{p}^w)}{1-T_i^\delta} - (\pi - \bar{\pi}^w)' E_\pi - b = 0.$$

2.2.3 Consistent aggregators for tariffs under TRQ

Tariff rate quotas (TRQ) are two-tiered tariff instruments where a lower (preferential) tariff rate is applied on imports until a pre-defined quota threshold is reached. Imports exceeding the quota level are subject to a higher, typically the Most Favored Nation (MFN), tariff rate. Many TRQs were introduced in the Uruguay Round of negotiations during the tariffication process, either to provide minimum market access to highly protected markets or to maintain pre-existing trade preferences. Although the number of tariff lines protected by TRQs has been decreasing in the last decade, they are still crucial border protection measures for agricultural trade (World Trade Organization, 2012). Additionally, TRQs are often introduced in the context of FTAs, at least during an intermediate implementation period.

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[6] For a formal proof consult Appendix B

The world trade of dairy products is traditionally complicated by TRQ regimes, such that inclusion of TRQs in the above model structure is relevant for our empirical section. The formal discussion below extends Anderson’s treatment (2009, Appendix A) of import quotas to the TRQ case. The implementation consists of two main elements: (1) a price mechanism that defines tariff inclusive domestic prices depending on the relations between fill rate, excess demand and supply and (2) an assumption on how the quota rent is allocated between the home country and exporters, the so-called quota allocation share. That share primarily depends on the quota administration method (Boughner et al., 2000) which is not regulated by the WTO, such that e.g. historical shares, first come, first serve or auctions are applied and quite different effective quota allocation shares found in practice.

Let us assume that there exist rent retaining tariff rates for all tariff lines, defining a price level (denoted with the price vector τ) up until quota rents are retained fully in the home country. Quota rents exceeding τ are partly attributed to the foreign country, according to the shares vector s**.** The per unit quota rent retained at home then can be calculated as:

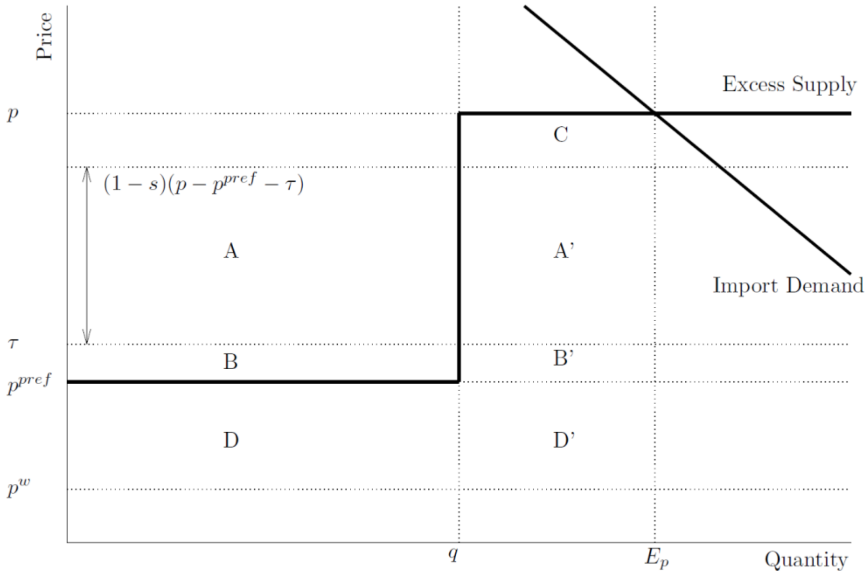
$$\tau + (1-s)(p - \bar{p}^{w} - \tau) = s\tau + (1-s)(p - \bar{p}^{w}).$$

Quota rents allocated to the importer country appear in the balance of trade as lump sum transfers to consumers and only accrue if the quota is filled. Above the threshold normal tariff revenues are collected at the out-of-quota rate. After partitioning the excess demand into in-quota and out-of-quota imports $E_p = (E_p^{in}, E_p^{out})$, the balance of trade condition takes the form:

$$E(p,q,\pi,u) - \underbrace{\left[s\tau + (1-s)(p - \bar{p}^{pref})\right]' E_p^{in}}_{\text{quota rent retianed at home}} - \underbrace{(\bar{p}^{pref} - \bar{\mathrm{p}}^{w})' E_p^{in}}_{\text{in-quota tariff revenue}} - \underbrace{(p - \bar{p}^{w})' E_p^{out}}_{\text{out-of-quota tariff rev.}} - (\pi - \bar{\pi}^{w}) E_{\pi} - b = 0,$$

where $\bar{p}^{pref}$ denotes import prices at the in-quota tariff rate. Income accrued to the home country from the TRQ regime is the sum of tariff revenues and a share of quota rents in our modeling setup. These two sources of income are depicted on Figure 2.1 for the small country case, assuming the TRQ is overfilled. Imports $\left(E_p\right)$ are defined by the equilibrium of excess supply and import demand. Areas D, $(A+B)$ and $\left(A' + B' + C + D'\right)$ correspond to in-quota tariff revenues, quota rent retained at home and out-of-quota tariff revenues respectively.

Figure 2.1: Partitioning tariff revenues and quota rents in the small country case



Source: own illustration

Our aim of substituting the TRQ mechanisms at the tariff line with an aggregate equivalent tariff rate does not allow for the above partitioning of E_p in the aggregate balance of trade condition. Therefore, we opt for an alternative formulation and first calculate both the quota rent and the in-quota tariff revenue for the entire import volume (areas $A+A'+B+B'$ and $D+D'$, respectively). Then we add on top of it a correction for the out-of-quota tariff revenues, corresponding to the area C. That correction is calculated based on the difference between the out-of-quota rate and the unit quota rent retained at home:

$$(p-\bar{p}^{pref})-\tau-(1-s)(p-\bar{p}^{pref}-\tau)=s(p-\bar{p}^{pref})-s\tau.$$

Plugging it in the balance of trade condition yields:

$$\begin{aligned} E(p,q,\pi,u)-\left[s\tau+(1-s)(p-\bar{p}^{pref})\right]' E_p I^q-(\bar{p}^{pref}-\bar{p}^{w})'E_p \\ -\left[s(p-\bar{p}^{pref})-s\tau\right]'\left(E_p-q\right)I^{out}-(\pi-\bar{\pi}^{w})E_\pi-b=0, \end{aligned} \tag{2.11}$$

where q denotes the vector of quota thresholds. I^{out} and I^{q} are vectors at tariff line level indicating whether quotas are overfilled such that a correction on out-of-quota imports is needed, respectively quotas filled such that quota rents occur.

The domestic price p above is derived from a model-endogenous price mechanism. Following a popular approach, the TRQ regimes in our modeling framework are represented by orthogonality constraints in an MCP framework (Junker and Heckelei, 2012, see appendix there for details).

In order to reach an aggregate form of equation (2.11), additional terms need to be introduced. The aggregator for the rent retaining tariff rates is defined as:

$$T^R = \sum_j w_j T_j^R,$$

where w_i are value shares and $T_j^R = s_j \tau_j / p_j$.

The trade weighted average tariff for the remaining quota rent takes the form:

$$\hat{T}^a = \sum_j w_j \hat{T}_j : \quad \hat{T}_j = \frac{(1-s_j)(p_j - \bar{p}_j^{pref})}{p_j} \quad \text{where } E_j^{in} \geq q_j.$$

Similarly, we introduce two tariff aggregators for the out-of-quota correction term:

$$\hat{T}^{a,corr} = \sum_j w_j \hat{T}_j^{corr} : \quad \hat{T}_j^{corr} = \frac{s_j(p_j - p_j^w)}{p_j}, \text{ where } E_j^{out} > 0$$

and:

$$T^{R,corr} = \sum_j w_j T_j^{R,corr} : \quad T_j^{R,corr} = \frac{s_j \tau_j}{p_j}, \text{ where } E_j^{out} > 0.$$

The in-quota tariff revenues are covered by the aggregator:

$$\hat{T}^{\mathrm{a,pref}} = \sum_j w_j T_j^{\mathrm{a,pref}} : \quad T_j^{\mathrm{a,pref}} = \frac{\left(\bar{p}_j^{pref} - \bar{p}_j^w\right)}{p_j}.$$

Substituting the above terms in equation (2.11), the tariff revenue part can be substituted with a combination of six tariff aggregators[7]:

$$\begin{aligned} & E\left(\frac{\phi(p^w)}{1-T^\delta}, q, \pi, u\right) - E_\phi \frac{\phi(p^w)}{1-T^\delta}\left[\hat{T}^a + T^R + \hat{T}^{a,pref}\right] \\ & \qquad - E_\phi \frac{\phi(p^w)}{1-T^\delta}\left[\hat{T}^{a,corr} - T^{R,corr}\right] + T_q - (\pi - \bar{\pi}^w)E_\pi - b = 0. \end{aligned} \tag{2.12}$$

The aggregator T_q in equation (2.12) is a correction term calculated over the quota threshold:

$$T_q = \left[s\left(p - \bar{p}^w\right) - s\tau\right]' qI^{out} = \sum_{j|E_j^{in} > q_j} q_j \left[s_j(\mathrm{p}_j - \bar{p}_j^w) - \mathrm{s}_j \tau_j\right].$$

The tariff aggregators covering tariff revenues and quota rent can be directly matched with the areas depicted on Figure 2.1, namely: $(A + A' + B + B') \sim \left(\hat{T}^a, T^R, T_q\right)$, $C \sim \left(\hat{T}^{a,corr}, \hat{T}^{R,corr}\right)$ and $(D + D') \sim \left(\hat{T}^{a,pref}\right)$.

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[7] A formal proof can be found in Annex C.

The extension to heterogeneous exporter regions is straightforward and results in the following (regionally extended) version of the equilibrium condition:

$$
\begin{aligned}
E\left[\frac{\varphi_1(\bar{p}^w)}{1-T_1^\delta},\ldots,\frac{\varphi_n(\bar{p}^w)}{1-T_n^\delta},\pi,u\right]-\sum_i E_{\phi_i}\frac{\varphi_i(\bar{p}^w)}{1-T_i^\delta}(\hat{T}_i^a+T_i^R+\hat{T}_i^{a,pref}) \\
-\sum_i E_{\phi_i}\frac{\varphi_i(\bar{p}^w)}{1-T_i^\delta}(\hat{T}_i^{a,corr}-T_i^{R,corr})+T_q-(\pi-\bar{\pi}^w)'E_\pi-b=0,
\end{aligned}
$$

(2.13)

where the i subscript runs over the exporter sub-regions. The $(T_i^R, T_i^{R,corr}, \hat{T}_i^a, \hat{T}_i^{a,corr}, \hat{T}_i^{a,\text{pref}})$ regional tariff aggregators are derived by including an explicit regional dimension, following the same approach as in section 2.2.2.

The definition of regional tariff aggregators requires information on the fill rate with respect to imports from different exporter sub-regions. This, on the other hand, implies that the quota threshold of the TRQ must be allocated between the sub-regions a-priori. The a-priori quota allocation limits the competition between the sub-regions for preferential imports.

The rent allocation parameters and the shadow rates are crucial for the TRQ mechanism, but unfortunately, they are largely unknown in applied work. In the special case of no rent retaining tariffs $(\tau=0)$ and zero allocation shares $(s=0)$, for example, $\hat{T}^{a,corr}, \hat{T}^{R,corr}$ and T_q all become zero and the extended equilibrium condition only differs from (1.1) by the endogenous price determination under TRQ. This assumption is identical to a perfect quota auction mechanism that would allocate the rents fully to the importer country. Assuming $\tau=0$ and $s=1$, on the other extreme, would result in allocating the full rent to the exporters and so would eliminate quota rents from the equilibrium condition.

With appropriate combination of (s,τ) a large set of quota administration methods can be described. The estimation of such parameters is, however, out of the scope of this paper. Instead, in order to assess the robustness of our approach, a sensitivity analysis is performed in section 2.3.1.

2.3 Empirical examples

After the quite formal introduction of the previous sections, we provide a more applied perspective to the proposed tariff aggregation approach in a numerical example in section 2.3.1. Section 2.3.2 then evaluates our method through an assessment of the Korean dairy market in the EU-South Korea FTA. These empirical examples provide further insights into the proposed methodology[8].

2.3.1 An applied perspective

Let us consider a small open economy where final demand is depicted by two levels of separability: between product groups and between domestic and imported goods within a particular group. The first level of separability enables us to concentrate on consumer decisions regarding one product group only in the further discussion. The second level of separability, on the other hand, enables

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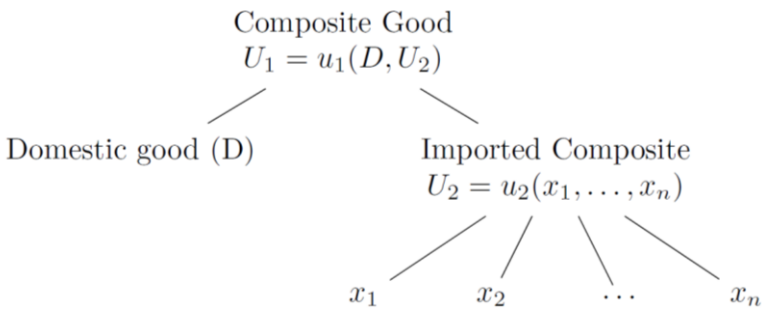
[8] The GAMS code and data of the numerical examples are available as supplementary material to this manuscript.

defining sub-utility functions for imports and calculating total (group) utility as the function of the sub-utility functions and the domestic goods.

As typical in applied equilibrium models, a nested CES functional form is chosen for our demand system (implying homotheticity), with uniform substitution elasticities at both levels (Figure 2.2). The consumption of domestically produced goods is represented by one single composite good D. Consumer expenditures are allocated to domestic and imported composites at the first stage (based on appropriate composite price indexes), while imports are allocated to the single import flows $(x_1,\ldots,x_n)$ at the second stage, independent of total expenditures on imports.

Figure 2.2: Nested Armington demand structure for imported goods



Source: own illustration

The aim of the aggregation exercise is to completely remove the lower nest (that defines the imported composite) from the simulation model and thus to collapse the consumers' budget allocation problem to the first stage only. In a first step, a world price and an ad-valorem tariff rate for the imported composite are defined that is equivalent in terms of expenditures on imports. Due to the homogeneity of the expenditure function, the ad-valorem equivalent for the imported composite is identical to a uniform tariff rate applied on all trade flows at the lower nest. That uniform tariff rate is conceptually the previously introduced T^{exp} that can be derived either by solving the equilibrium model for a uniform tariff rate at the lower nest, or by closed form solutions (provided e.g. by Bach and Martin 2001).[9]

Applying this uniform tariff rate in the tariff revenue function too would, however, lead to a bias in the simplified balance of trade: the difference between expenditures and tariff revenues would open up (or close). That bias comes from the different marginal impacts of a change in tariffs on expenditures and tariff revenues (Bach and Martin, 2001, page 628). In order to correct for the bias, the second step of the aggregation exercise defines a different uniform tariff rate for the tariff

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[9] It would be also possible during aggregation to account for the fact that the production costs of the domestic good comprise imported intermediates of which tariffs might change, too. That would require adding the impact on BOT and considering the resulting price changes for the domestic good. That possibility is however not taken into account in the following discussion. It requires firstly further assumptions on substitution between intermediate inputs and other (intermediate) factors in production, including their impact on factor prices. Secondly, assumptions with regard to the substitution between the imported composite and the domestic good need to be introduced as well. This approach would require solving all considered nests simultaneously.

revenue function. The uniform tariff rate can be derived by fixing tariff revenues at the upper nest and numerically solving the equilibrium model for a uniform tariff rate at the lower nest.

Unlike in the first step, the uniform tariff for the tariff revenues is not the correct ad-valorem equivalent that could be directly applied at the upper nest. Substituting single tariff rates with a uniform one implies a change in the import mix and so an adjustment both in the average world price and the total imported quantities. At the same time, switching off the lower nest would imply that tariff revenues are calculated based solely on the average world price and the imported composite U_2. Thus the uniform tariff rate needs to be corrected to these two effects before plugging it as ad-valorem equivalent in the upper nest: both the adjustment in the average world price and the difference between total imports in quantity terms and in utility terms need to be taken into account.

When setting up a similar framework, Bach and Martin (2001) made the domestically produced good the price numeraire and assumed it as non-tradable in order to eliminate the GDP function from the balance of trade condition of equation (2.1). That leads them to define their ‘simplified balance of trade function’, at the expense of counter-intuitive results in trade liberalization scenarios: imports at fixed world prices (a quantity index of imports) decreased. Reducing tariffs increased the share of those imported goods facing relatively higher tariffs and therefore having a higher marginal utility per unit in the benchmark, because the CES utility aggregator requires smaller import volumes of these goods to reach the same level of utility. Here we relax somewhat these strong restrictions on the supply side. Following Anderson (2009) we assume that the domestic price of the domestically produced good D is defined fully by the (fix) world prices, and allow for a substitution between domestic and imported goods at the same time by making the domestic good exportable. That assumption still leads to the simplified balance of trade function, but delivers more intuitive results in trade liberalization scenarios (increasing imports due to the substitution effect). Still, as indicated above, we refrain from taking impacts of tariff liberalization on production costs into account.

In order to tackle heterogeneous exporter regions in our framework, the Rest of the World is split up into two single countries $(n=2)$, both of them facing the same tariff schedule but having different compositions of trade. The balance of trade condition of (2.13) in this case takes the form:

$$\begin{aligned} p_c\bar{M} &- \sum_{i=1}^{2} E_{\phi_i} \frac{\varphi(p^w)}{1-T_i^{\delta}} (\hat{T}_i^{a} + T_i^{R} + \hat{T}_i^{a,pref}) \\ &- \sum_{i=1}^{2} E_{\phi_i} \frac{\varphi(p^w)}{1-T_i^{\delta}} (\hat{T}_i^{a,corr} - T_i^{R,corr}) + T_q - b = 0, \end{aligned} \tag{2.14}$$

where p_c is the composite price index, defined as:

$$p_c = \left[\beta_d p_d^{(1-\sigma)} + \sum_{j=1}^{n} \sum_{j=1}^{m} \beta_{i,j} p_{i,j}^{(1-\sigma)} \right]^{1/(1-\sigma)} \tag{2.15}$$

$\bar{M}$ denotes total imports in the benchmark, σ is the substitution elasticity, b is the balance of trade in the benchmark, and the exporter sub-regions are indexed with j. The CES utility aggregators satisfy the separability and homogeneity conditions, and so T_i^{δ} can be calculated with the sequential numerical approach of equation (2.10). The import demand quantities E_{ϕ_i} are calculated in this pre-step as well. In the numerical example below we further assume uniform world prices equal to unity $\left(p^w = \mathbf{1}\right)$, which allows for a further simplification: $\varphi_i(p^w) \equiv 1, \quad \forall i = 1,2.$ This selection of the world prices also implies that the functional relationship of equation (2.4) between T^{exp} and T^{δ} holds in our results. The tariff aggregators $(\hat{T}_i^{a}, \hat{T}_i^{a,pref}, \hat{T}_i^{a,corr}, T_i^{R}, T_i^{R,corr}, T_q)_{i=1}^{n}$ can be derived directly from the formulas in section 2.2.3.

The benchmark data on imports and expenditures are identical to those in Bach and Martin (2001) to allow for direct comparison (Table 2.1). Trade policies are defined over six tariff lines with a dispersed tariff structure. Expenditure on domestic goods equals to 2000 while the substitution elasticity is set to 2. In order to illustrate the extended tariff aggregation technique, some tariff lines are protected by TRQs with zero preferential rates and high MFN rates such that TRQs are filled. Consequently, shadow rates, and so quota rents, are positive in the benchmark. Our illustrative trade liberalization scenario assumes no tariff reduction, as was in the case in Bach and Martin (2001), but an expansion of the quota thresholds.

Table 2.1: Benchmark and scenario assumptions

	Benchmark				Liberalization scenario	
Tariff lines	Applied rates	Quota threshold	Expenditure on imports at world prices		Applied rates	Quota threshold
	both regions	both regions	R1	R2	both regions	both regions
t1	10	-	100	-	10	-
t2	10	-	-	100	10	-
t3	10	-	-	100	10	-
t4	200*	100	100	-	**	120
t5	200*	100	-	100	**	120
t6	200*	100	100	-	**	120

* shadow rate,i.e. the tariff rate of the marginal imports under TRQ

** tariff rates of the marginal imports under TRQs depend on the changes in import demand and are therefore not know a-priori

Source: own elaboration

In the benchmark point the Bach-Martin aggregator pair and the TRI, reported under the whole exporter region, are identical to the numerical example of Bach and Martin (2001), see Table 2.2. This equivalence requires two crucial assumptions regarding the TRQs: (1) the shadow rate under TRQ is identical to the applied rates in the Bach-Martin example and (2) quota rents are fully attributed to the importer region. That also implies that the aggregators $(\hat{T}_i^{a,corr}, T_i^{R}, T_i^{R,corr}, T_q)_{i=1}^{n}$ are all zero, greatly reducing the complexity of equation (2.14). Results in the liberalization scenario are necessarily different from those in Bach and Martin (2001): our quota expansion scenario implies much higher tariff aggregators (and so higher rate of protection) as the substantial tariff cuts did in Bach and Martin (2001).

The True Average Tariff and the Bach-Martin aggregator for the expenditure function are conceptually identical. The main difference is that the former measures the average tariff content relative to an average domestic price, while the latter measures the same tariff content relative to an average world price. Average world prices being lower than the (tariff inclusive) domestic prices, the TAT must be smaller than the Bach-Martin aggregator for the expenditure function.

Table 2.2: Different aggregated tariffs in percentages terms

	Benchmark				Liberalization scenario			
	Own calculation			Bach-Martin*	Own calculation			Bach-Martin*
	R1	R2	full region	full region	R1	R2	full region	full region
Bach-Martin, expenditure func.	171%	120%	149%	149%	142%	103%	126%	27%
Bach-Martin, tariff rev. func.			96%	96%			92%	27%
True Average Tariff	63%	54%	60%		59%	51%	56%	
TRI			178%	178%			149%	29%
MacMap-type aggregator	104%	57%	81%		4%	7%	6%	

* simulation result from the didactic example in Bach and Martin (2001, p. 631)

Source: own calculation

To calculate trade weighted average tariffs, the TRQ regime needs to be converted into an equivalent tariff rate (AVE). A popular approach, underlying the MacMap database, derives the AVE according to the market regime (Bouet et al., 2008). When the quota is clearly underfilled (<90%) then the associated AVE is set to the preferential rate. If the quota is considered binding (fill rate between 90% and 99%[10]), the AVE is set at the average of preferential and MFN rates. Fill rates >99% indicate an overfilled quota where the AVE is set equal to the MFN rate. The approach suffers from the consequences of setting the quota rent arbitrarily and from fixed trade weights that ignore regime shifts. As imports under TRQ are fixed, an expansion of a binding quota typically delivers a huge drop in the MacMap type aggregator: the AVE drops from the MFN rate to the average of the MFN and the preferential rate. The same is likely to happen if TRQs are moderately overfilled. This is an extreme case of what has already been reported in the literature, that fix weighted aggregators underestimate the level of trade restriction and inconsistently measure the gains from trade liberalization (Kee et al., 2008).

Welfare consistent aggregators, on the other hand, depend on the parameterization and benchmark data of the underlying optimization model. Increasing the substitution elasticity, for example, would allow for larger changes in the consumption bundle, implying larger impacts on consumer expenditure and consequently higher values for TAT and TRI. A sensitivity analysis demonstrates that dependency of the tariff indexes on the model parameterization (Figure 2.3). The indexes are calculated for a random sample drawn for the substitution elasticity; assuming uniform distribution over the interval (2, 15) and using a sample size of 1000. All three welfare consistent tariff indexes increase, as expected, with the substitution elasticity, illustrating that the gap between welfare

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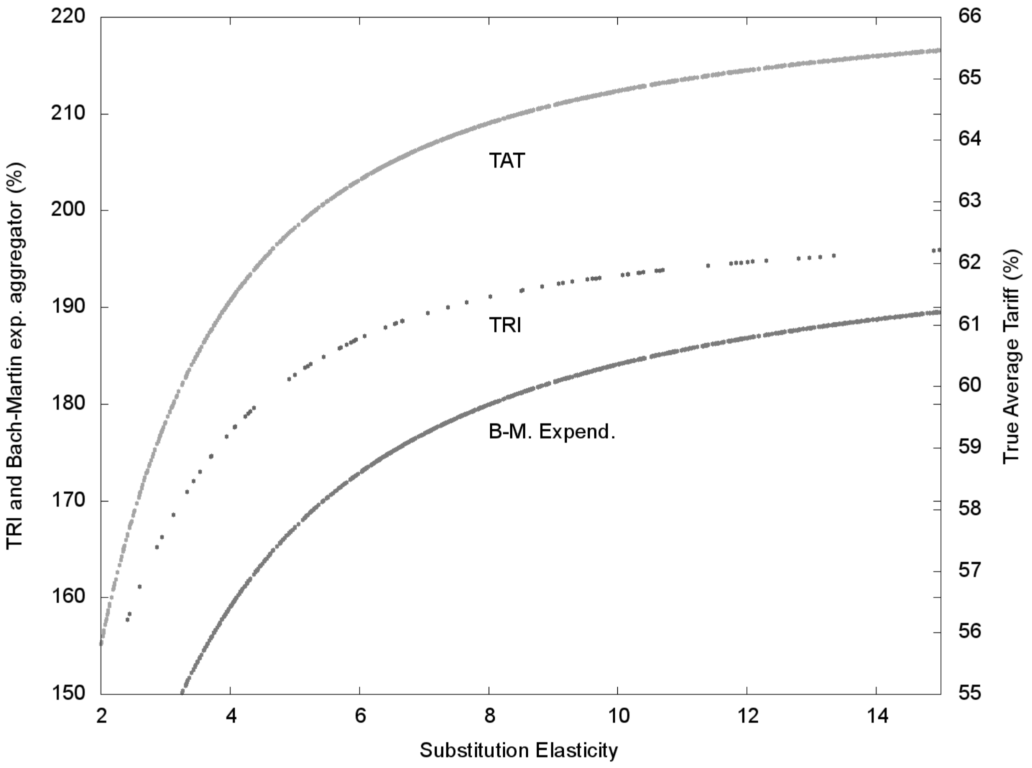
[10] The choice of the middle range (90-99%) depends on the errors in the underlying statistical trade databases. Even totally filled quotas can be reported as slightly under filled due to statistical errors.

consistent and fix weighted (conventional) aggregators is clearly affected by model-parameterization.

Figure 2.3: Dependence of the welfare consistent tariff aggregators on the substitution elasticity (liberalization scenario)



Source: own illustration

Our simulation results at the tariff line level (under the constant utility assumption) indicate a welfare gain in the liberalization scenario, measured as a decrease in the balance of trade (Table 2.3). The import shares change in favor of exporter region R1 as imports under expanded TRQs, mainly sourced from this region, becomes dominant. A slight substitution of domestic goods with imports takes place, generating exports of the domestic good at the same time. The positive welfare impact can also be seen from expenditures savings at domestic prices (-119).

Table 2.3: Welfare results at the tariff line level (‘true’ values in value terms)

	Benchmark			Liberalization scenario		
	R1	R2	full region	R1	R2	full region
Expenditure on imports at domestic p.	710	520	1230	735	521	1256
Tariff revenues (incl. quota rent) at domestic p.	410	220	630	402	215	617
Expenditure on imports at world p.	300	300	600	333	306	638
Total expenditure at domestic p.			3230			3111
Balance of trade at domestic p.			600			494

Source: own calculation

The retrieved ‘true’ values by running our model at the tariff line level are in Table 2.4 compared to the different tariff aggregators. The optimal combination of the aggregators $(T^{\delta}, \hat{T}^{a}, \hat{T}^{a,corr}, \hat{T}^{a,pref}, T^{R}, T^{R,corr}, T_{q})$ reproduces the change in overall welfare, total expenditure and tariff revenues. Furthermore, the regionally extended aggregators reproduce expenditure and tariff revenues not only in total, but also with respect to imports from specific exporters. Clearly, the conventional MacMap-type aggregators deliver biased welfare results, even if they are calculated at a finer geographical resolution[11].

Table 2.4: Welfare results of the test runs with different tariff aggregators (percentage difference to ‘true’ values)

Welfare item	Regional/total	MacMap-type agg.	MacMap-type agg. (regional version)	Optimal combination	Optimal combination (regional version)
Tariff revenues	R1		-93%		0%
	R2		-86%		0%
	total	-90%	-91%	0%	0%
Expenditure on imports (at domestic prices)	R1		2%		0%
	R2		-17%		0%
	total	-6%	-5%	0%	0%
Total expenditure	total	-21%	-22%	0%	0%
Balance of trade	total	-18%	-22%	0%	0%

Source: own calculation

The TRI index is strongly affected by quota allocation parameters because quota rents retained at home are modeled as government revenues, and those enter directly the balance of trade function. Allowing part of the quota rent being allocated to exporter countries would quite intuitively increase the TRI as the TRI summarizes the impact of trade restrictions on the own country’s welfare. If some of the quota rent escapes to the rest of the world, the impact of the TRQ regime on the home country welfare must be stronger than before. The relationship between TRI and the rent allocation shares is further explored in Annex D, including a sensitivity analysis.

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[11] The regional version of the MacMap-type aggregator is calculated as trade weighted averages over imports from specific exporter sub-regions.

2.3.2 Application to dairy markets in the EU-South Korea FTA

The EU-South Korea FTA analyzed in here is the first of a new generation of so-called comprehensive free trade agreements of the EU which address far more aspects of bilateral trade than import duties. Still, our focus remains on the negotiated tariff schedule. The impact of the FTA on the European dairy exports provides a test case for the techniques developed in the previous sections for two reasons. On the one hand, the EU exporter countries enjoy the same preferential access, but supply different commodity mixes to the Korean market. The emerging tariff dispersion justifies the use of those advanced regional aggregation techniques over exporters that we introduced in section 2.2.2. On the other hand, the dairy market is traditionally complicated by TRQ instruments, methodologically addressed in section 2.2.3.

The EU has the third highest import share in the Korean dairy market of around 14% in 2012 (USDA, 2013) following the USA and New Zealand. EU dairy imports face ad-valorem tariffs and bilateral TRQs which are progressively cut respectively expanded in the FTA for most of the tariff lines over a 16 year period. The assessment below derives Member State-specific tariff aggregators taking into account the TRQ mechanisms in force on the market. The empirical model shares many of the assumptions of the equilibrium framework developed in the didactic example, however now applied to a more diverse exporter region with a more dispersed tariff structure. Furthermore, substitution elasticities now differ at the two CES nests: 7.3 is chosen for the lower nest according to the econometric estimate in (Hertel et al., 2007), while the upper nests assumes more sticky shares with only half of the above[12]. Dairy products are represented by 21 HS-6 tariff lines of which 12 are protected by TRQs. Trade flows in the benchmark are from the COMEXT database, tariff and TRQ (changes) follow the legislative text of the FTA, and are simulated for the years 2016 and 2026

Following the compensation variation approach of the theoretical sections, simulations are performed under the fix utility assumption. Adjustments in the balance of trade, i.e. changes in the financial inflow necessary to close the balance, are then indicating the monetary compensation needed to leave overall welfare in the economy unchanged. The pre-model aggregation technique we developed in the previous sections is ignorant of the exact shocks (here trade liberalization) later used in scenario analysis. The aggregation is only reliant on the equilibrium states, including the assumed supply and demand structures, which also makes the fix utility assumption reasonable in our case. That type of aggregation is hence highly suitable for applied work, as it only affects the benchmark and need to be repeated for each shock analyzed.

The composition of Korean dairy imports from single EU countries is heterogeneous, leading to differences in the calculated regional tariff aggregators (Table 2.5). Aggregated tariffs for those countries exporting more under TRQs are typically lower, as they take advantage of the preferential market access. The relative size of the derived tariff aggregators are in line with the findings of Manole and Martin (2005): assuming the CES functional form and positive substitution elasticities, the tariff revenue aggregator is always lower or equal to the trade expenditure aggregator. The comparison also reveals that the MacMap-type aggregator with fixed trade weights underestimates border protection in case of significant quota increases.

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[12] The sensitivity of the different tariff aggregators to the substation elasticity is explored in section 2.3.1 above. Here we focus on providing a use case for the proposed aggregation method and do not repeat the sensitivity analysis exercise.

Table 2.5: Tariff aggregators in percentage terms

	True Average Tariff	Trade exp. agg.	Tariff revenue agg.	MacMap-type agg.
		2010		
Belgium	60%	149%		95%
Germany	62%	163%		114%
France	51%	105%		34%
Netherlands	54%	119%		62%
Rest of EU	48%	91%		43%
All countries	**57%**	**134%**	**93%**	**126%**
		2016		
Belgium	54%	119%		68%
Germany	57%	133%		100%
France	41%	68%		3%
Netherlands	46%	85%		34%
Rest of EU	33%	49%		5%
All countries	**54%**	**118%**	**59%**	**118%**
		2026		
Belgium	49%	94%		0%
Germany	55%	123%		98%
France	37%	60%		0%
Netherlands	39%	64%		22%
Rest of EU	30%	43%		0%
All countries	**52%**	**108%**	**40%**	**115%**

Source: own calculation

A remarkable outcome of our simulations is that the trade balance is worsening in the course of the FTA implementation (Table 2.6). This impact is also reflected in the increasing TRI index over the implementation period. Decreasing welfare in the small country case as an impact of trade liberalization seems to contradict basic results of trade economy. An important point to recognize is, however, that by simulating under fix utility and without factoring in impacts of tariff revenues in the consumer decision problem[13], the balance of trade condition becomes non-binding. More precisely, it is the variable financial inflow that closes the trade balance in our framework, and not anymore the equivalence of excess supply and import demand. The standard welfare calculation is also further complicated by the assumption that producer prices are independent of trade policies and so changes in producer surplus are ruled out. As a direct consequence, there is nothing left to guarantee a welfare improvement in trade liberalization scenarios. In other words, the sub-model used for tariff aggregation only accounts for the allocative efficiency gains at the lower Armington nest, which alone does not need to compensate for the losses in tariff revenues. Integrating the welfare consistent tariffs in a full CGE should clearly heal that deficiency.

Table 2.6: Welfare-related simulation results for South Korea

		2010	2016	2026
Total consumer expenditure, at domestic p.	Mio.EUR	1003	953	917
Expenditure on imports, domestic p.	Mio.EUR	727	724	718
Expenditure on imports, world p.	Mio.EUR	439	529	581
Expenditure on domestic good, domestic p.	Mio.EUR	276	229	199
Tariff revenues, at domestic p.	Mio.EUR	277	165	104
Quota rents, at domestic p.	Mio.EUR	11	30	32
Financial inflow*	Mio.EUR	439	482	504
TRI	%	195%	214%	223%

* The balance of trade is defined as total consumer expenditures minus government revenues from border protection instruments minus the value of the domestically produced good

Source: own calculation

Although simplified, the above modeling framework is still relevant for testing the consistency of the proposed tariff aggregation. In order to evaluate the impact of choosing different tariff aggregators, we perform a simulation exercise by plugging in the tariff aggregators in a model version featuring one single EU region only. The simulated results are then systematically compared to those derived with the model operating at the tariff line level (Table 2.7). Our regional extension of Anderson's optimal tariff combination clearly outperform the standard one in exactly reproducing welfare results at the finer geographical resolution. Calculating conventional (MacMap-type) aggregators at the regional scale, however, does not significantly improve the welfare-consistency of aggregate model results.

The test runs with the MacMap-type aggregators resulted in higher welfare gains than the 'true' impact calculated with the tariff line model. Both the drop in total consumer expenditure to reach

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[13] The underlying behavioral assumption is that each individual consumer is too small to change tariff revenues significantly with the adjustments in his consumption bundle. Therefore individuals do not take into account the change they imply in tariff revenues in their consumption decisions (Gilbert and Tower, 2012).

the same utility and the improvement in the balance of trade were pronounced. This impact is largely due to the AVE representation of TRQs. Even moderate quota expansions are perceived by the MacMap-type aggregator as large reductions in the AVE, if the quota fill rate is close to 100% in the calibration point, and the preferential rate is significantly lower than the MFN one. The MacMap-type aggregator therefore overestimates welfare gains and the trade facilitating impact of quota expansions.

So far, literature always found that conventional, fixed weighted aggregators underestimate welfare gains. Laborde et al. (2011) find that conventional tariff aggregators underestimate the gains in real income from global trade liberalization by around 76% at the global scale. Anderson (2009), simulating a unilateral trade liberalization for India, reports that e.g. efficiency gains are dramatically underestimated with fixed weighted aggregators (¼ to 1/50 of the true gains). Our results indicate that the opposite direction is also possible under more complex trade policy instruments such as TRQs.

Table 2.7: Relative bias in reproducing the true welfare items with different tariff aggregators (year 2016)

		2016			
		MacMap type (uniform across all exporters)	MacMap type (different across exporters)	Anderson's optimal combination	Anderson's optimal combination -- regional extension
Expenditure on domestic good, domestic p.		0.1%	-55%	0%	0%
Expenditure on imports, domestic p.	imports originated in				
	Belgium	2%	-7%		0%
	Germany	50%	-54%		0%
	France	-81%	271%		0%
	Netherlands	-65%	29%		0%
	Rest of EU	-91%	60%		0%
	Rest of the World	60%	-88%		0%
	Total	0%	-8%	0%	0%
Total consumer expenditure, at domestic p.		0%	-19%	0%	0%
Gov. revenue from border protection	imports originated in				
	Belgium	60%	8%		0%
	Germany	221%	-10%		0%
	France	25%	43%		0%
	Netherlands	35%	135%		0%
	Rest of EU	-35%	-5%		0%
	Rest of the World	111%	-83%		0%
	Total	101%	-45%		0%
Balance of trade		-41%	-20%	0%	0%

Source: own calculation

2.4 Summary and conclusions

Although its strong theoretical foundations have been already developed, welfare consistent tariff aggregation has not yet gained ground in the impact assessment of FTAs. In this paper, we show that it is numerically feasible to derive welfare consistent tariff aggregators from data at the detailed tariff line level. In order to tackle the bilateral aspects of FTAs, we extend the Anderson (2009) framework of welfare consistent aggregators with an explicit regional dimension. Specifically, we develop a sequential numerical method to derive regional versions of the True Average Tariff under the assumption of separable homotheticity. Flexible and welfare consistent tariff aggregation is then possible by combining the regional aggregators in the balance-of-trade condition of our modeling framework.

The Anderson framework is not only flexible in terms of introducing the explicit regional dimension to the tariff aggregation problem; it also allows a straightforward inclusion of complex border protection measures such as TRQs. We define a combination of seven tariff aggregators in a modified balance of trade condition to aggregate tariffs and TRQs in a welfare consistent manner. The technique is capable of addressing quota rent allocation directly. The importance of the (largely unknown) rent allocation on simulation results is further addressed in Annex D.

The extended tariff aggregation framework is applied both to a didactic example and to an evaluation of the Korean dairy market in the EU-South Korea FTA. Our results support the previous findings in the literature that conventional fixed weighted tariff aggregators introduce a serious bias in aggregated welfare results. Somewhat surprisingly, this bias leads to an overestimation of the welfare gains in the specific settings of our FTA simulations.

The approach presented above aggregates the border protection instruments pre-model into an ad-valorem rate that afterwards can be integrated in larger AEMs. The proposed aggregation method correctly summarizes the welfare impacts of trade policy reforms at the tariff line under specific behavioral assumptions that are usually met in the CET/CES nested structures of contemporary CGE models. But the presented welfare consistent aggregators do not provide a general solution to remove any bias from tariff aggregation for all modeling purposes. While these aggregators correctly summarize welfare impacts of trade liberalization, shocks in e.g. the non-trade policy parts of CGE models might not be correctly captured. Specifically, the preceding aggregation scheme does not allow for relative price changes on the supply side in the commodity group being aggregated (Anderson, 2009). Shocks e.g. in the supply part of the CGE model structure would lead to relative price changes and thus to inconsistencies between the initial price wedges represented by the proposed tariff aggregators and the resulting equilibrium price differences.

The tariff aggregation clearly depends on the parameterization and input data of the underlying model, and so encapsulates much more information than the tariff structure itself, as demonstrated with a sensitivity analysis based on different substitution elasticities. It is also unable to factor in the effect of (prohibitive) tariffs which lead to zero-trade flows[14]. Furthermore, aggregated tariffs are derived under the assumption of fixed consumer utility, which is not directly compatible with standard applied equilibrium modeling practices and might provoke counterintuitive welfare results as only welfare gains from trade on the import side are considered. Last but not least, compared to conventional aggregators, the welfare consistent aggregators require additionally data on consumption at the aggregate level.

These findings directly lead to recommendations for empirical work. Against the background that welfare consistent aggregators clearly outperform simple trade weighted averages in our own, but also any application found in literature so far, at least their use for pre-model aggregation can be clearly recommended. The GAMS code available from the authors underlines that its application is nowadays no longer a demanding exercise once disaggregated data are available. This can be tariff line data or more detailed sectoral and regional Social Accounting Matrices to be aggregated.

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[14] The MacMap methodology builds on average trade shares from similar countries to overcome the zero trade issue. Such an approach could potentially be used with the welfare consistent aggregators too.

The illustrative scenario on the EU-South Korea FTA above is too restricted to derive serious policy recommendations from the simulated result. It therefore remains for further research to test the extended aggregation technique in application of large-scale AEMs, where the simultaneous cross-sectoral effects of FTAs can be observed. Here, the implementation of the proposed technique should allow for impact analysis and related policy recommendations that are not subject to two biases of conventional tariff aggregation methods: (1) aggregation over exporter regions with significant tariff dispersion and (2) variable tariff rates determined by TRQ regimes.

2.5 References

Anderson, J.E., 2009. Consistent Trade Policy Aggregation*. Int. Econ. Rev. 50, 903–927. doi:10.1111/j.1468-2354.2009.00553.x

Anderson, J.E., Neary, J.P., 1994. Measuring the Restrictiveness of Trade Policy. World Bank Econ. Rev. 8, 151–169. doi:10.1093/wber/8.2.151

Anderson, J.E., Neary, J.P., 2005. Measuring the restrictiveness of international trade policy. MIT Press, Cambridge, Mass.

Bach, C.F., Martin, W., 2001. Would the right tariff aggregator for policy analysis please stand up? J. Policy Model. 23, 621–635. doi:10.1016/S0161-8938(01)00077-1

Bouet, A., Decreux, Y., Fontagne, L., Jean, S., Laborde, D., 2008. Assessing Applied Protection across the World. Rev. Int. Econ. 16, 850–863.

Boughner, D.S., de Gorter, H., Sheldon, I.M., 2000. The economics of Two-Tier Tariff-Rate import quotas in agriculture. Agric. Resour. Econ. Rev. 29, 58–69.

Brockmeier, M., Bektasoglu, B., 2014. Model structure or data aggregation level: Which leads to greater bias of results? Econ. Model. 38, 238–245. doi:10.1016/j.econmod.2014.01.003

Bureau, J.-C., Salvatici, L., 2004. WTO Negotiations on Market Access in Agriculture: a Comparison of Alternative Tariff Cut Proposals for the EU and the US. Top. Econ. Anal. Policy 4.

Deaton, A., Muellbauer, J., 1980. Economics and consumer behavior. Cambridge University Press, Cambridge.

Gilbert, J.P., Tower, E., 2012. Introduction to numerical simulation for trade theory and policy. World Scientific, Singapore.

Grant, J.H., Hertel, T.W., Rutherford, T.F., 2007. Tariff line analysis of U.S. and international dairy protection. Agric. Econ. 37, 271–280. doi:10.1111/j.1574-0862.2007.00251.x

Guimbard, H., Jean, S., Mimouni, M., Pichot, X., 2012. MAcMap-HS6 2007, an exhaustive and consistent measure of applied protection in 2007 (Working Paper No. 2012-10). CEPII research center.

Hertel, T., Hummels, D., Ivanic, M., Keeney, R., 2007. How confident can we be of CGE-based assessments of Free Trade Agreements? Econ. Model. 24, 611–635. doi:10.1016/j.econmod.2006.12.002

Horridge, M., 2008. GTAPAgg: Data Aggregation Program (Chapter 5), in: Global Trade, Assistance, and Production: The GTAP 7 Data Base.

Horridge, M., Laborde, D., 2008. TASTE a program to adapt detailed trade and tariff data to GTAP-related purposes. 11th Annual Conference on Global Economic Analysis, Helsinki, Finland.

Junker, F., Heckelei, T., 2012. TRQ-complications: who gets the benefits when the EU liberalizes Mercosur’s access to the beef markets? Agric. Econ. 43, 215–231. doi:10.1111/j.1574-0862.2011.00578.x

Kee, H.L., Nicita, A., Olarreaga, M., 2008. Import Demand Elasticities and Trade Distortions. Rev. Econ. Stat. 90, 666–682. doi:10.1162/rest.90.4.666

Laborde, D., Martin, W., van der Mensbrugghe, D., 2011. Measuring the Impacts of Global Trade Reform with Optimal Aggregators of Distortions (No. 01123), Discussion Papers. IFPRI: Markets, Trade and Institutions Division.

Manole, V., Martin, W., 2005. Keeping the devil in the details: A feasible approach to aggregating trade distortions. Presented at the 7th Annual Conference of the European Trade Study Group, Dublin.

Martin, W.J., 1997. Measuring Welfare Changes with Distortions, in: Applied Methods for Trade Policy Analysis. Cambridge University Press.

McCleery, R., DePaolis, F., 2014. So you want to build a trade model? Available resources and critical choices. Econ. Model. 40, 199–207. doi:10.1016/j.econmod.2014.03.017

Narayanan, B.G., Aguiar, A., McDougall, R. (Eds.), 2012. Global Trade, Assistance, and Production: The GTAP 8 Data Base.

Narayanan, B.G., Hertel, T.W., Horridge, J.M., 2010. Disaggregated data and trade policy analysis: The value of linking partial and general equilibrium models. Econ. Model. 27, 755–766. doi:10.1016/j.econmod.2010.01.018

Pelikan, J., Brockmeier, M., 2008. Methods to Aggregate Import Tariffs and their Impacts on Modeling Results. J. Econ. Integr. 23, 685–708.

Rutherford, T.F., 1995. Extension of GAMS for complementarity problems arising in applied economic analysis. J. Econ. Dyn. Control 19, 1299–1324. doi:10.1016/0165-1889(94)00831-2

USDA, 2013. Dairy and Products Annual, Republic of Korea (GAIN Report No. KS1347). USDA Foreign Agricultural Service.

World Trade Organization, 2012. Tariff quota administration methods and fill rates 2002-2011.

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2.6 Annex

2.6.1 Appendix A

In order to show the equivalence of $(\varphi_i)_{i=1}^n$ and $(\hat{\varphi}_i)_{i=1}^n$ we first reformulate the definition of the latter in equation (2.10), by applying Euler's theorem on homogeneous functions. For the sake of simplicity we drop the price vector π . This simplification does not alter the validity of our results.

$$\sum_i \frac{\partial p_c}{\partial p_i} p_i = p_c(p) \doteq p_c(\hat{\varphi}_i(p), p^{-i}) = \sum_{j \neq i} \frac{\partial p_c}{\partial p_j} p_j + \frac{\partial p_c}{\partial \varphi_i} \cdot \frac{\partial \varphi_i}{\partial p} \cdot p_i, \quad \forall i \in \{1 \ldots n\}$$

$$\frac{\partial p_c}{\partial p_i} p_i = \frac{\partial p_c}{\partial \varphi_i} \cdot \frac{\partial \varphi_i}{\partial p} p_i, \ \forall i \in \{1 \ldots n\}$$

By substituting the above expression back into equation (2.9), we show that the conditions for the $(\varphi_i)_{i=1}^n$ aggregators are satisfied too:

$$p_c(\varphi_1(p), \ldots, \varphi_n(p)) = \sum_i \frac{\partial p_c}{\partial \varphi_i} \cdot \frac{\partial \varphi_i}{\partial p} p_i = \sum_i \frac{\partial p_c}{\partial p_i} p_i = p_c(p).$$

2.6.2 Appendix B

Anderson's optimal combination of tariff aggregators in the balance of trade function can be substituted with an equivalent combination of exporter-specific aggregators, in case of separable homothetic consumer preferences.

Recognizing that the $(\varphi_i)_{i=1}^n$ aggregators, defined in equation (2.7) inherit the homogeneity property from the expenditure function:

$$\varphi_i T_i^a = \sum_j p_{i,j} \frac{\partial \varphi_i}{\partial p_{i,j}} T_{i,j} = \sum_j p_{i,j} \frac{\partial \varphi_i}{\partial p_{i,j}} \frac{(p_{i,j} - \bar{p}_{i,j}^w)}{p_{i,j}} = \varphi_i'(p_i - \bar{p}_i^w), \ \forall i.$$

Reformulating the tariff revenues by plugging in the regional aggregators yields:

$$(p - p^w)' E_\phi \phi_p = \sum_i (p_i - p_i^{\,w})' E_{\phi_i} \phi_{p_i} = \sum_i (p_i - p_i^{\,w})' \varphi_i E_{\phi_i} = \sum_i \varphi_i T_i^{\,a} E_{\phi_i} = \sum_i T_i^{\,a} E_{\phi_i} \frac{\varphi_i(p^w)}{1 - T_i^\delta}$$

In other terms, the optimal combination of tariff aggregators can be broken down to a sum of optimal combinations:

$$T^a E_\phi \frac{\phi(\bar{p}^w)}{1 - T^\delta} = \sum_i T_i^{\,a} E_{\phi_i} \frac{\varphi_i(\bar{p}^w)}{1 - T_i^\delta}.$$

Substituting this expression into equation (2.6) yields the regional version of the balance of trade condition:

$$E\left[\frac{\varphi_1(\bar{p}^w)}{1 - T_1^\delta}, \ldots, \frac{\varphi_n(\bar{p}^w)}{1 - T_n^\delta}, \pi, u\right] - \sum_i T_i^{\,a} E_{\phi_i} \frac{\varphi_i(\bar{p}^w)}{1 - T_i^\delta} - (\pi - \bar{\pi}^w)' E_\pi - b = 0.$$

2.6.3 Appendix C

It is possible to define a welfare consistent combination of the tariff aggregators defined in section 2.2.3 in the aggregated balance of trade condition. Exploiting the homogeneity of ϕ we show that the following equations hold:

$$\phi T^R = \sum_j p_j \phi_{p_j} T_j^R = \sum_j p_j \phi_{p_j} \frac{s_j \tau_j}{p_j} = (s\tau)' \phi_p,$$

$$\phi \hat{T}^a = \sum_j p_j \phi_{p_j} \hat{T}^a = \sum_j p_j \phi_{p_j} \frac{(1-s_j)(p_j - p_j^w)}{p_j} = \left[(1-s)(p-p^w)\right]' \phi_p,$$

$$\phi \hat{T}^{a,pref} = \sum_j p_j \phi_{p_j} \hat{T}^{a,pref} = \sum_j p_j \phi_{p_j} \frac{(p_j^{pref} - p_j^w)}{p_j} = (p^{pref} - p^w)' \phi_p,$$

$$\phi \hat{T}^{a,corr} = \sum_j p_j \phi_{p_j} \hat{T}^{a,corr} = \sum_{j|E_j^{out}>0} p_j \phi_{p_j} \frac{s_j (p_j - p_j^w)}{p_j} = s(p-p^w)' \phi_p,$$

$$\phi T^{R,corr} = \sum_j p_j \phi_{p_j} T^{R,corr} = \sum_{j|E_j^{out}>0} p_j \phi_{p_j} \frac{s_j \tau_j}{p_j} = (s\tau)' \phi_p.$$

Substituting these expressions in the tariff revenue part of equation (2.11) yields:

$$\begin{aligned}
&\left[s\tau + (1-s)(p-\bar{p}^w)\right]' E_p I^q + (\bar{p}^{pref} - \bar{p}^w)' E_p + \left[s(p-p^w) - s\tau\right]' (E_p - q) I^{out} \\
&= (s\tau)' E_p I^q + \left[(1-s)(p-\bar{p}^w)\right]' E_p I^q + (\bar{p}^{pref} - \bar{p}^w)' E_p + (s(p-p^w))' E_p I^{out} \\
&-(s\tau)' E_p I^{out} - \left[s(p-p^w) - s\tau\right]' q I^{out} \\
&= \phi T^R E_\phi + \phi \hat{T}^a E_\phi + \phi \hat{T}^{a,pref} E_\phi + \phi \hat{T}^{a,corr} E_\phi - \phi T^{R,corr} E_\phi - \left[s(p-p^w) - s\tau\right]' q I^{out} \\
&= E_\phi \frac{\phi(p^w)}{1-T^\delta} \left[T^R + \hat{T}^a + \hat{T}^{a,pref}\right] + E_\phi \frac{\phi(p^w)}{1-T^\delta} \left[\hat{T}^{a,corr} - T^R\right] - T_q.
\end{aligned}$$

Substituting this back to the balance of trade condition results in equation (2.13).

2.6.4 Appendix D

In section 2.3.1 we gave an intuitive explanation why TRI should increase if quota rents are allocated away from the home country. In this appendix the functional relationship between quota rent allocation and the TRI is further explored and illustrated. Let us adapt the balance of trade condition from equation (2.1) for the case when quota rents are explicitly modeled:

$$B(p,u,\bar{p}^w) = E(p,u) - (p-\bar{p}^w)' E_p - R(p,\bar{p}^w,u) - b = 0,$$

where we simplified by taking out those consumption goods that are not subject to aggregation (with price vector π), and introduced the function $R()$ for the quota rents. The TRI index is then defined by a uniform tariff rate $(1+t^\Delta)$ that covers quota rents:

$$t^{\Delta}: E\left((1+t^{\Delta})\bar{p}^{w},u\right)-\left((1+t^{\Delta})\bar{p}^{w}-\bar{p}^{w}\right)' E_{p}=E(p,u)-(p-\bar{p}^{w})'E_{p}-R(p,\bar{p}^{w},u)=b.$$

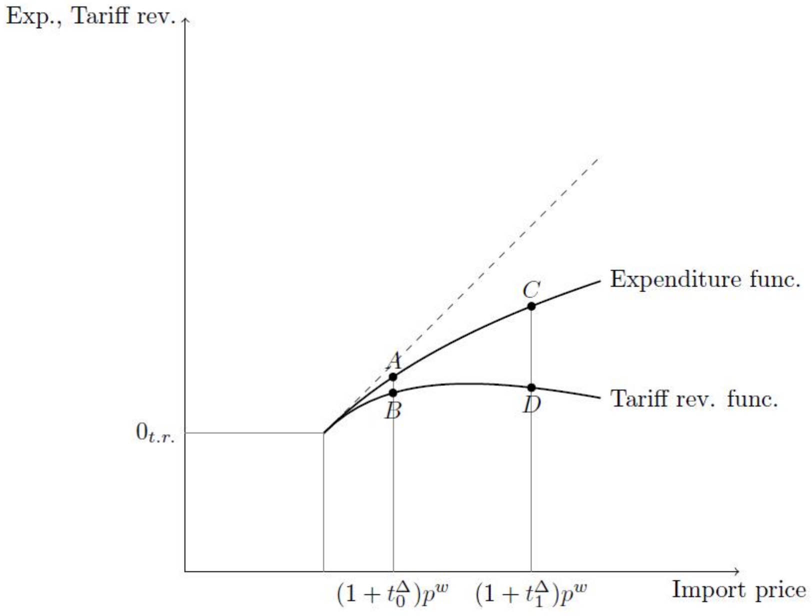
The difference between expenditure and tariff revenues on the left hand side is equal to financial inflow (b). This difference is illustrated for the benchmark case on Figure 2.4 with the segment $\overline{AB}$. The benchmark TRI is marked $(1+t_0^{\Delta})$.

The shapes of the expenditure and tariff revenue functions crucially define the impact of allocating rent to exporters. The tangent of the expenditure function is equal to the optimal demand (by the Shephard's lemma) and so it is a decreasing function of t^{Δ}. The marginal impact of tariff increase on the tariff revenues is larger, illustrated by a more concave functional specification on Figure 2.4:

$$\frac{\partial E_p(p,u)(p-p^w)}{\partial p}=E_p+E_{pp}(p-p^w)\geq E_p.$$

In order to illustrate the impact of allocating away quota rents from the home country, we set quota rents retained at home to zero: $R\equiv 0$. As the rent retained at home has no impact on the optimal consumption bundle (discussed in section 2.3.1), the financial inflow must close the balance, and therefore it must increase with the initial quota rents. As a result, the difference between expenditures and tariff revenues under the uniform tariff rate $(1+t^{\Delta})$ must meet the increased inflow $\left(\overline{CD}\right)$. As the marginal impact of a tariff increase on tariff revenues is larger than on expenditures (see above), this forces the optimal tariff to move to the right on the horizontal axis and increase to $(1+t_1^{\Delta})$.

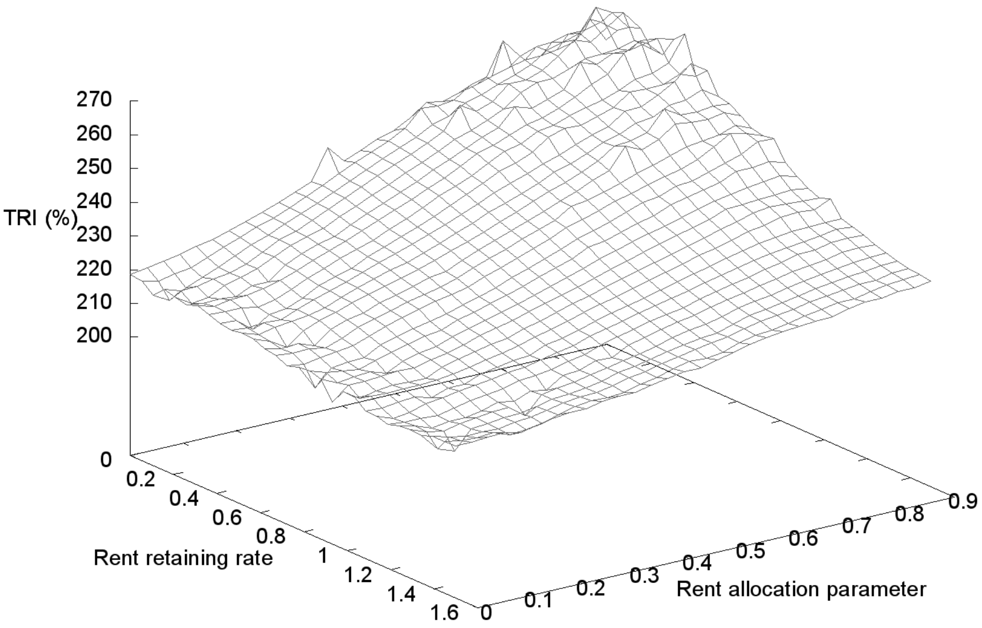
Figure 2.4: Impacts of removing quota rent on the TRI



Source: own illustration

We further explore the sensitivity of TRI with respect to the rent allocation parameters with a numerical simulation exercise (Figure 2.5). The TRI is calculated for a random sample drawn from independent uniform distributions for the rent retaining rate and the rent allocation parameter with a sample size of 1000. Clearly, trade restrictiveness of TRQs increases when allocating more rent to foreign countries (either by decreasing the rent retaining rate τ or the or by increasing the rent allocation parameter s). Similarly, low rent retaining rates result in lower quota rents retained in the home country and in higher TRI indices, respectively.

Figure 2.5: TRI under different combinations of the Rent retaining tariff rate and the Rent allocation parameter



Source: own elaboration

Chapter 3: Multipurpose tariff aggregation in global trade models: the case of tariff dismantling on the Swiss beef market[15]

Abstract

In this paper, we develop and compare two aggregation techniques that both take advantage of international trade data at the tariff line level. Three important sources of aggregation bias are addressed. (i) first the substitution effects at the tariff line, i.e. that the composition of imported commodity groups and therefore the weights in the aggregation of individual tariff lines might change due to trade liberalization; (ii) also the “water” in tariffs, i.e. that imperfect transmission of tariff cuts to domestic prices can have significant impacts on tariff liberalization outcomes; (iii) and finally they address the endogenous determination of tariffs under Tariff Rate Quotas (TRQs) and the associated shifts in applied tariff rates. The techniques we propose can be implemented as extensions to global trade models without significantly altering core model structures, thereby making their implementation in contemporary models relatively easy. Unlike consistent tariff aggregation, that is designed to be consistent with a selected economic variable (e.g. welfare) but can increase aggregation bias for other results, we propose alternatives that decrease aggregation bias for a wider range of model variables. With that we aim at providing multipurpose tariff aggregation alternatives that can be used for complex policy impact analysis covering a whole range of economic impacts. The tariff aggregators are tested for tariff dismantling scenarios on the Swiss beef market. The simulations are carried out with a global, large-scale partial equilibrium model of the agricultural sector (CAPRI), here extended with the proposed tariff aggregation approaches. We demonstrate that the proposed techniques allow for channelling tariff line level impacts to more aggregated levels of trade modelling.

Keywords: tariff aggregation, Tariff Rate Quotas, beef market, Trade liberalization, water in tariffs

JEL: F13, F15, Q17, Q18

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[15] An earlier version of this chapter has been presented as Himics, M., Listorti, G., Tonini, A. (2017). "Advanced tariff aggregation in global trade models: dismantling tariffs on the Swiss beef market." at the 2017 International Congress of the European Association of Agricultural Economists (EAAE), Parma, Italy and available online on AgeconSearch: https://ageconsearch.umn.edu/record/261284

3.1 Introduction

Market access policies are typically defined at the detailed tariff line level[16]. The “tariff schedule” of a country normally includes thousands of tariff lines, and trade statistics are also recorded at this fine level of disaggregation. As trade negotiation (tariff cuts, exceptions to tariff cuts, sensitive products etc.) are made at the tariff line level both in bi- and multilateral trade talks, the disaggregated tariff data (tariff distributions) should be taken into account when assessing the economic impacts of trade policy reforms. Most empirical models of international trade, however, cannot fully take advantage of such disaggregated available data when working with aggregated commodities, each of them often covering a wider array of tariff lines.

The straightforward way for better exploiting existing datasets at the tariff line level would be to extend trade models to the tariff line. There are indeed some attempts in the literature in this direction. Grant et al. (2007) link in an iterative manner a Computable General Equilibrium (CGE) model with a satellite partial equilibrium (PE) model for the dairy products. Narayan et al. (2010) opt for a nested approach for extending a general equilibrium (GE) model with PE module working at the tariff line level for the impact assessment of the tariff liberalization for the Indian auto industry. Britz and van der Mensbrugghe (2016) advocates advanced database filtering methods and algorithmic improvements to avoid pre-model aggregation. These examples, however, still offer only partial solutions, as they either do not cover all sectors or they still do not disaggregate the model to tariff lines. Computational and data issues still force practitioners to stick to more aggregated commodity and regional groups in applied trade modelling. Statistics on both demand and supply are still lacking at the tariff line level and, when extending import demand systems to the tariff line, the number of possible bilateral trade flows quickly becomes computationally unmanageable. Practitioners are, therefore, confronted with the choice of a tariff aggregation method that fits both their modelling tools and the objective of their modelling exercise.

Unfortunately, tariff aggregation is often subject to several sources of biases in the simulated impacts of trade policy reforms. In the context of gravity estimations Anderson and Wincoop (2004) identifies those dimensions of the aggregation where aggregation bias occurs; across trading partners, across goods and policy instruments. The literature is, however, inconclusive about the empirical magnitude and even the direction of the aggregation bias. While e.g. French (2016) finds a downward bias in a flexible model allowing for comparative advantage across products for every country, Bektasoglu et al. (2016) calculate an upward bias in estimating non-tariff measures with traditional gravity modelling techniques, or Anderson (2009) finds an upward bias too in a Computable General Equilibrium (CGE) analysis.

In this paper we focus on three specific sources of aggregation bias, namely the (i) substitution effect at the tariff line, the (ii) "water" in tariffs and the (iii) impact of Tariff Rate Quotas (TRQ). To the best of our knowledge, this is the first attempt in the literature to propose tariff aggregators addressing the three sources of bias above. The selection of the above sources is primarily motivated by the specificities of the empirical application of the proposed tariff aggregation methods: the Swiss beef

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[16] The Nomenclature of the Convention on the Harmonized Commodity Description and Coding System, or “HS Nomenclature”, elaborated under the auspices of the World Customs Organization, comprises about 5,000 commodity groups identified by a 6-digit code and arranged according to a legal and logical structure. The Swiss tariff schedule comprises additional 8-digit subdivisions, which is the level of disaggregation considered in this paper.

market is characterized by significant "water" in tariffs, it is also regulated by a complex system of TRQs, and the substitution effect between different beef products is likely to be significant. Nevertheless, the above three sources of aggregation bias are relevant for a wider range of policy applications too. The binding overhang (related to the tariff "water" and defined as the gap between the bound and the applied MFN rates) still seems to be relevant when assessing trade policies (Beshkar et al., 2015), TRQs are still crucial border protection measures for agri-food markets (WTO, 2012), and the price sensitivity of consumers that can lead to substitution effects in the consumption is particularly important in developing and low-income countries (Muhammad et al. 2017). Thus there is room to exploit the possibilities of the proposed aggregators in future research in applied trade modelling.

The first source of aggregation bias we are focusing on is linked to the heterogeneity of commodity groups. Trade liberalization often leads to significant changes in the composition of the commodity group, which is a demand side adjustment to relative price changes. Assuming fix relative shares in trade flows within a commodity group, as done in standard tariff aggregation, is often too restrictive. If some particular tariff lines within a commodity group are subject to significantly lower or higher initial tariffs, or in case tariff lines are liberalized to a different extent, a significant change in the relative import shares can be expected. In fact, the issue of fix trade shares within commodity groups already hinders the correct implementation of tariff schedules (and their change) in aggregate global equilibrium models. Tariff cuts for commodity groups that are calculated with the fix shares assumption already introduce trade liberalization scenarios with a large degree of approximation.

The second source of aggregation bias is due to an imperfect transmission of tariff cuts to reductions in domestic prices. We refer to the part of the applied tariff rate that needs to be eroded before tariff cuts have a direct impact on the domestic price as the “water” in tariffs. This is somewhat different from the standard binding overhang definition in literature, which is the difference between bound and applied rates (e.g. Bchir et al. 2006). Our definition is more data intensive as it requires detailed information on domestic prices. In the presented modelling exercise these data are available due to a specific dataset on Swiss domestic prices. Both definitions of "water" refer to the buffer that countries have in trade negotiations to lower bound tariffs without impacting current applied tariffs. Under a fix world price assumption it also creates a buffer for negotiating offers without impacting domestic prices of imported goods. Conventional tariff aggregation techniques are based on simple price wedges and they calculate domestic prices simply by adding applied tariffs on top of world prices. In this paper we highlight the importance of the “water” in tariffs in tariff aggregation, and we provide an appropriate methodology taking advantage of a detailed database for Swiss domestic prices for beef products.

Finally, we cover the endogenous determination of tariffs under TRQ as an important source of aggregation bias. In a TRQ system the applied tariff rate changes depending on the quota fill rate (and therefore on the level of imports). Standard aggregation techniques do not always take that into account, or at least not at the tariff line level, that leads to an over or underestimation of the applied tariff rate. As a substantial proportion of agricultural production in developed countries is protected by TRQs (see for example de Gorter and Kliauga, 2006), the TRQ issue is especially relevant for agri-food markets. As the Swiss beef market is also characterized by a complex TRQ system, the issue is highly relevant for our empirical example. We propose two approaches to aggregate tariffs under TRQ by taking into account the model-endogenous adjustment of applied tariff rates depending on quota fill rates.

We propose and develop two different approaches to adjust for the above aggregation biases. The trade expenditure aggregator (TE) is an equivalence measure of tariff protection, defined as the uniform tariff rate that is equivalent with a set of individual tariffs in terms of its impact on trade expenditures (see also Himics and Britz, 2016). Calculating trade expenditures requires setting up an import demand system at the tariff line level for the TE aggregator, which in turn enables us to calculate with the changes in the composition of commodity groups. The TE aggregator, as we propose here, also includes explicit TRQ functions at the tariff line level to take into account the adjustments in applied tariff rates under TRQ.

In the second approach, we increase the complexity of a typical outcome measure[17] (weighted average tariff) through endogenous aggregation weights based on the demand responses of a Constant Elasticity of Substitution (CES) import demand system, defined at the tariff line level. The Tariff Reduction Impact Model for Agriculture (TRIMAG) aggregator takes into account the changes in the optimal consumption mix due to relative price changes after a certain tariff dismantling rule is applied (see also Listorti et al., 2013). Assuming (and parameterizing) a specific import demand system allows the TRIMAG aggregator taking into account substitution effects at fine (8-digit level) level of the tariff lines. As in the case of the TE aggregator, only responses in consumer expenditure are considered, and the welfare impacts of tariff revenues are here neglected. This characteristic allows also for a more straightforward assessment and comparison of the two aggregation approaches. Ignoring the income effect of foregone tariff revenues seems not too restrictive in the PE framework used and presented in this paper, or in case tariff revenues has little impact on consumer income[18].

TRIMAG takes advantage of its unique database of domestic and c.i.f. import prices of agri-food products at the very detailed 8-digit level, and calculates with the "water" in tariffs explicitly. By estimating the "water" in tariffs, TRIMAG addresses the imperfect price transmission of tariff cuts to domestic prices. TRIMAG also calculates for the aggregated commodity groups in- and out-of-quota rates, which can be directly plugged into aggregate trade models.

Therefore we cover all three sources of aggregation biases identified above: changes in the composition of the imported mix, “water” in the tariffs and TRQs. The features of each aggregators included in this paper are summarized in Table 3.1.

We test the proposed two aggregators by analyzing alternative Swiss tariff dismantling scenarios for beef imports. We follow a two-stage, comparative static approach that is typical in applied trade

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[17] We follow the definition of outcome measures by Cipollina and Salvatici (2008), and define those as measures based on policy variables and weights. Although some economic effects might be taken into account when calculating outcome measures, they remain a-theoretic since they are not originally constructed according to equivalence criteria.

[18] Most of the literature on tariff aggregation in the general equilibrium simply channels tariff revenues to government or to consumers in the form of a lump sum transfer (Bach and Martin 2001, Anderson 2009). In a PE framework, such as the one developed later in this paper, that covers only a limited number of commodities (e.g. agri-food markets), and without the economic agent of the government that re-distributes tariff revenues in the economy, the substitution effect is expected to outweigh the income effect. Therefore ignoring the latter effect might be justified.

modelling (Francois et al., 2005, Philippidis and Sanjuán, 2007, Egger et al., 2015 to name a few). First we estimate aggregated ad valorem equivalent (AVE) tariff rates using disaggregated data. Second, we plug in the estimated AVEs in a partial equilibrium (PE) model working with more aggregate product definitions. More precisely, both the TE and TRIMAG aggregators are implemented as pre-model aggregation modules in the same large-scale global PE modelling framework, the Common Agricultural Policy Regionalized Impact (CAPRI) model (e.g. Britz and Witzke 2014), which renders systematic direct comparison possible. Assuming different tariff dismantling scenarios for the EU beef exports to Switzerland, both pre- and post-reform aggregated tariffs are calculated with the TE and TRIMAG approaches. In order to evaluate the performance of the proposed aggregators in policy impact assessment, the aggregated tariffs are plugged into CAPRI and the economic impacts of the liberalization scenarios are simulated.

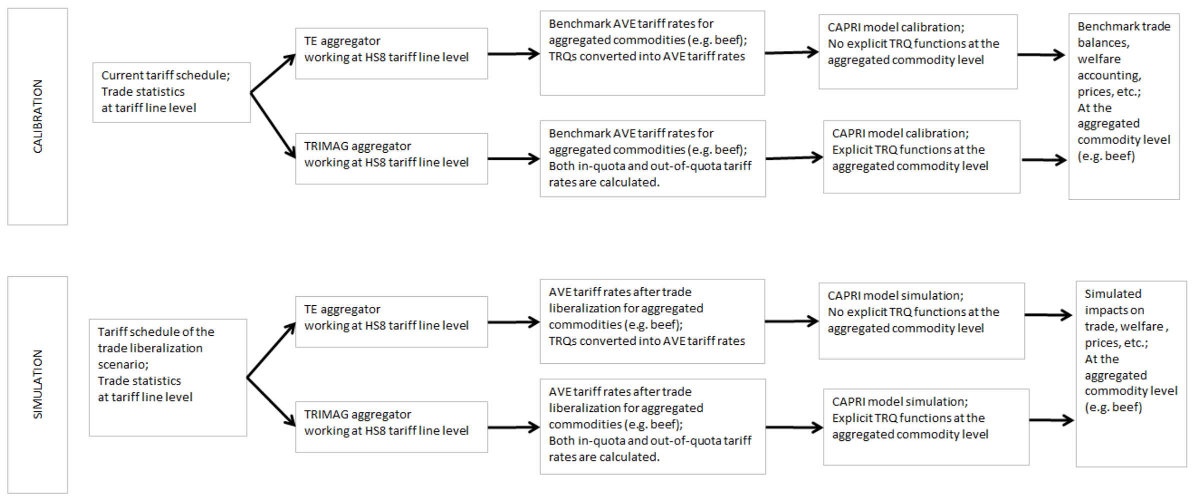
Table 3.1: Properties of tariff aggregators in respect to selected aggregation biases

	Traditional (fixed weight) aggregators	**Trade Expenditure (TE) aggregator**	**TRIMAG aggregator**
Substitution effect at the tariff line level	Not taken into account	via CES import demand system	via CES demand system for aggregation weights
Water in tariffs	Not taken into account	Not taken into account	Explicitly taken into account using a specific dataset on domestic and c.i.f. prices
Tariff Rate Quotas (TRQs)	via tariff equivalent; fix applied rate	via tariff equivalent; variable applied rate with explicit TRQ functions	Via TRQ function at aggregate level; calculates both aggregated in quota and out of quota rates

Source: Own comparison

A more precise illustration of the modelling approach is presented on Figure 3.1, also comparing it to traditional, fixed weight aggregation. First we calculate the current aggregated tariffs for CAPRI with the different tariff aggregation modules. Those enter the calibration process of CAPRI acknowledging the different aggregated tariffs the aggregation methods can provide: a single ad valorem equivalent tariff in the TE aggregator versus both in-quota and out-of-quota tariff rates in TRIMAG. The calculated aggregated ad valorem equivalent tariffs contribute to define the so-called CAPRI reference scenario used as a yardstick in our analysis. In simulation, the aggregated tariffs corresponding to the tariff schedule of the trade liberalization scenarios are calculated with the two aggregation approaches. The aggregated tariffs are then plugged into CAPRI that in turn provides the simulated impacts on trade (market balances and prices) and welfare for the different policy scenarios.

Figure 3.1: Extended modelling approach with pre-model tariff aggregation modules



Source: own illustration

The paper is structured as follows. Section 3.2 and 3.3 formally introduce the TE and TRIMAG tariff aggregation approaches, respectively. Section 3.4 shortly describes the CAPRI model. Section 3.5 defines the application to the Swiss beef market as well as the test tariff dismantling scenarios. Data and simulation results are presented and discussed in Section 3.6. Concluding remarks are reported in Section 3.7.

3.2 The trade expenditure (TE) tariff aggregator

The TE aggregator, as we define below, is conceptually equivalent to the expenditure aggregator originally proposed by Bach and Martin, (2001) and to the true average tariff of Anderson (2009). More precisely, we introduce the TE aggregator here following the regionally explicit approach of Himics and Britz, (2016), using mostly their notation and sometimes referring back to that paper for further references. Previous literature identified the TE aggregator as a component of welfare-consistent tariff aggregation for the general equilibrium framework. Our contribution here is to identify the TE aggregator as a stand-alone aggregation alternative, embedded in a two-step modelling approach. Opting for the Himics and Britz (2016) variant of the TE aggregator is exactly motivated by the needs of the second (aggregate) modelling step: exporter-specific AVE tariffs for the aggregate commodities. We also discuss the specific aggregation biases this approach can address, and provide an empirical case to assess the magnitude for the possible correction of biases in Section 3.6.

The TE aggregator aims to derive a uniform tariff that is equivalent to the set of individual tariffs in terms of their impact on trade expenditures. In order to quantify the impact we need to construct a demand system based on the following trade expenditure function:

$$E(p,v,u) = e(p,u) - r(p,v) \tag{3.1}$$

where p denotes the domestic price vector, including both a domestically produced and imported goods. v is the vector of input prices, u denotes consumer utility, $e(p,u)$ and $r(p,v)$ are the expenditure and GDP (revenue) functions respectively. The trade expenditure function is concave and homogenous of degree one in p and convex in v. The domestic price vector is wedged away from world prices by an ad valorem tariff vector τ ("price gap approach"):

$$p = (1 + \tau)p^{w} \tag{3.2}$$

The TE aggregator is defined by an implicit function of the domestic price vector:

$$\phi: \mathbb{R}^{n} \longrightarrow \mathbb{R} \mid E(\phi(p), v, u) = E(p, v, u) \tag{3.3}$$

where n is the number of imported goods. We follow a compensation variation approach and keep utility fixed at the initial level. Furthermore, the input price vector is assumed not to be affected by changes in output prices, allowing us to drop u and v below for the sake of brevity. The TE aggregator represents the aggregate price wedge relative to an average world price:

$$t^{TE} = \frac{\phi(p) - \phi(p^{w})}{\phi(p^{w})} \tag{3.4}$$

Following Himics and Britz, (2016) we extend the above implicit function to cover explicitly each exporter region $1 \dots m$:

$$\varphi_1, \dots, \varphi_m\colon\ \mathbb{R}^{n \times m} \longrightarrow \mathbb{R}^{m} \mid E[\varphi_1(p), \dots, \varphi_m(p), u] = E(p, u) \tag{3.5}$$

The regionally explicit version of the TE aggregator then can be defined as:

$$t_i^{TE} = \frac{\varphi_i(p) - \varphi_i(p^{w})}{\varphi_i(p^{w})}, \qquad \forall i \in \{1 \dots m\} \tag{3.6}$$

The equation system of (3.5) has no unique solution in general, but by exploiting separable homotheticity the problem can be rewritten using composite price indexes. As shown by Himics and Britz, (2016) the TE aggregators can then be derived independently, in a sequence, and a unique solution does exist:

$$\varphi_1, \dots, \varphi_m\colon\ \mathbb{R}^{n \times m} \longrightarrow \mathbb{R}^{m} \mid p_c\left[\varphi_i(p), p^{-i}\right] = p_c(p), \qquad \forall i = 1 \dots m \tag{3.7}$$

where p^{-i} is the domestic price vector of imported goods other than those originated in exporter region i and p_c denotes the composite price index. Using a constant elasticity of substitution (CES) form for the utility function with one domestically produced and n imported goods this can be expressed as:

$$p_c = [\beta_d p_d^{1-\sigma} + \sum_{i=1}^{m} \sum_{j=1}^{n} \beta_{i,j} p_{i,j}^{1-\sigma}]^{1/(1-\sigma)} \tag{3.8}$$

where β denotes calibrated share parameters, σ is the substitution elasticity and p_d denotes the price of the domestically produced good.

Note that the CES form in equation (3.8) implies the same substitution elasticity between different tariff lines and between products from different exporters. Laborde et al. (2017) apply a nesting strategy and implement a second CES nest for the same tariff line from different exporters below the nest of tariff lines belonging to the same composite commodity. They conclude that the substitution between tariff lines has a significantly larger impact on simulated results as the substitution between exporters. In our case, the inclusive PE model (CAPRI) includes a CES nest for imports of the same composite commodity from different trading partners. The exporter-specific AVE tariffs τ_i^{TE} from equation (3.6) enter that lower nest. As a consequence, our setup implies that substitution between disaggregated products (tariff lines) from the same exporter is covered entirely by the pre-model tariff aggregation module, while substitution between imports from different exporters is addressed by the import demand system of CAPRI.

In case a tariff line is subject to TRQ the $p_{i,j}$ prices also depend on the variable tariff rate. To capture the possible regime shifts from in-quota to out-of-quota situation (or vice versa) we further extend the above aggregation framework with explicit TRQ functions defined at the tariff line level. The following system of equations, in the form of complementarity slackness conditions, links the applied tariffs to imported quantities in the price transmission equation (3.2):

$$q - I_{in} \geq 0 \quad \perp \quad t_s \geq 0 \tag{3.9}$$
$$t_{out} - t_{in} \geq t_s \quad \perp \quad I_{out} \geq 0 \tag{3.10}$$
$$t_a = t_{in} + t_s \tag{3.11}$$
$$I = I_{in} + I_{out} \tag{3.12}$$

Equation (3.9) drives the regime switch; if in-quota imports I_{in} reach the quota limit q then the unit quota rent t_s (shadow tariff) becomes non-zero, representing an out-of-quota market regime. Equation (3.10) defines bounds for the shadow tariff that should be equal to the difference of in- and out-of-quota rates (t_{in} and t_{out} respectively) in case out-of-quota imports I_{out} occur. Equation (3.11) defines the endogenously determined applied tariff rates t_a based on the in-quota rate and the shadow rate, and finally equation (3.12) is the import balance defining total imports I. The equation system (3.9)-(3.12) is defined for all tariff lines that are subject to TRQs. In case TRQs are defined on a multilateral basis the quota thresholds are distributed a-priori between the trading partners.

With respect to the link to the CAPRI model, the aggregate (importer-specific) tariff rates of equation (3.6) are implemented in CAPRI as AVE tariff rates. As a result, the endogenous modelling of the TRQ system in the TE aggregator is shifted from CAPRI to the pre-model aggregation module. The advantage of shifting policies to the aggregation module is that TRQs can be also modelled at the tariff line level and not only at the aggregate commodity level of CAPRI (e.g. for the product beef).

It would be possible to calculate not only the TE aggregator, but also a tariff-revenue aggregator and opt for a tariff aggregation approach that is fully welfare consistent (Anderson 2009, Laborde et al. 2017). That approach, however, would require structural adjustments in the original model, such as the inclusion of a specific balance of trade constraint. We argue that the use of the TE aggregator alone still improves substantially the simulated key impacts on welfare and trade, especially in the partial equilibrium setup of our analysis on the Swiss beef tariff dismantling scenarios. At the same time, our approach does not require structural adjustments in the inclusive model.

3.3 The TRIMAG tariff aggregator

The TRIMAG model, developed by the Swiss Federal Office for Agriculture (FOAG) (Listorti et al., 2013), aggregates both current tariffs (reference mode) and tariffs modified according to possible trade scenarios (simulation mode). In the Swiss tariff schedule, in-quota and out-of-quota tariffs are registered under different tariff lines. All Swiss tariff lines are specific (expressed as a fixed charge per physical unit of imports) so, in order to perform the aggregation, they are first converted into ad valorem equivalents (shares of the value of the imported good) using the c.i.f. price. This is necessary since various 8-digits tariff lines corresponding to the same CAPRI product could have different levels of product transformation (e.g., fresh meat and meat preparations), but conversion factors from processed to base products are not available. For a given commodity, the aggregation is repeated separately for in-quota and out-of-quota tariffs, and for the main importing regions (EU and rest of the world RW; see section 3.5).

In the *reference mode*, three weighting methods are combined, each having an advantage from a particular point of view: (i) an import weighted average accounts for the source of origin of imports (EU or RW); (ii) a total imports weighted average focuses on the importance of the specific tariff line in the aggregated commodity (iii) a simple arithmetic average is free of the endogeneity bias associated with import weights, and that can also take into account tariffs without trade observations. The weights for the import weighted average (i) can be expressed as follows:

$$w^1_{ts,i,r} = \frac{V_{ts,i,r}}{\sum_{i=1}^{N} V_{ts,i,r}},\ \forall ts, i, r \tag{3.13}$$

Where *V* is the import value; *ts* is the subscript indicating the tariff scheme (in- or out-of-quota tariff and single tariff); *i* indicates the tariff lines, and *N* is the number of 8-digits tariff lines corresponding to the selected aggregate commodity; *r* (*r* = 1…*R*) is the regional subscript for the sources of origin. The weights of the total imports weighted average (ii) are as follows:

$$w^2_{ts,i} = \frac{\sum_{r=1}^{R} V_{ts,i,r}}{\sum_{i=1}^{N}\sum_{r=1}^{R} V_{ts,i,r}}. \tag{3.14}$$

The weights for the arithmetic average (iii) take the form of:

$$w^3_{ts,i,r} = \frac{I_{ts,i,r}}{\sum_{1=1}^{N} I_{ts,i,r}}, \tag{3.15}$$

where *I* is a binary variable indicating whether a tariff line *i* is covered by the aggregate commodity that is subject to the tariff aggregation. For each tariff line, the final aggregation weight under the reference mode $w^{REF}_{ts,i,r}$ is then simply defined as an arithmetic average of the above three:

$$w^{REF}_{ts,i,r} = \left(w^1_{ts,i,r} + w^2_{ts,i} + w^3_{ts,i,r}\right) \cdot \frac{1}{3} \tag{3.16}$$

The aggregate tariff for the commodity XX is then a weighted average using the above weights:

$$t^{REF}_{ts,XX,r} = \sum_{i=1}^{N} w^{REF}_{ts,i,r} \cdot t_{ts,i,r}, \tag{3.17}$$

where $t^{REF}_{ts,XX,r}$ is the aggregated applied ad valorem equivalent rate for the commodity XX in the *reference mode* for a given tariff scheme *ts* and source of origin *r*. $t_{ts,i,r}$ are the respective ad valorem tariffs of all tariff lines *i* assigned to commodity XX. Combining three weighting methods is similar to the approach taken in the standard CAPRI model, although TRIMAG performs the calculation at a finer, 8-digit, level.

In the *simulation mode*, TRIMAG provides the ultimate impact of tariff dismantling defined at the 8-digits level on the aggregated applied tariff rates. Aggregation weights change in respect to the *reference mode*. Indeed, the substitution effects in the consumption bundle are endogenously calculated, based on a CES demand system that mimics, under a fix utility assumption, the adjustments in the composition of the consumption mix triggered by relative price changes at the tariff line level. This is also similar to what the TE aggregator does. The CES demand system is calibrated to the weights of the *reference mode* as derived from above. Intuitively, if the relative price of a certain tariff line decreases due to tariff cuts, then its relative consumption, and therefore weight, within the aggregate commodity increases. The *simulation mode* is formally defined by the following set of equations,

$$U_{ts,XX,r} = \left[\sum_{i=1}^{n} \delta_i \cdot \left(w_{ts,i,r}^{SIM}\right)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}, \tag{3.18}$$

$$w_{ts,i,r}^{SIM} = w_{ts,NUM,r}^{SIM} \left[\frac{\delta_{ts,i,r}}{\delta_{ts,NUM,r}} \frac{p_{ts,NUM,r}}{p_{ts,i,r}}\right]^{\sigma}, \tag{3.19}$$

$$\sum_{i=1}^{n} \delta_{ts,i,r} = 1 \tag{3.20}$$

Where, for a given tariff scheme *ts* and source of origin *r*, $w_{ts,i,r}^{SIM}$is the aggregation weight of tariff line *i*; $U_{ts,XX,r}$ denotes consumers' utility; $\delta_{ts,i,r}$ is the share parameter calibrated to the reference weights $w_{ts,i,r}^{REF}$; $p_{ts,i,r}$ is the expected domestic wholesale price after tariff cuts; σ >0 is the elasticity of substitution; *NUM* indicates the numéraire tariff line. The aggregate tariff is then calculated as:

$$t_{ts,XX,r}^{SIM} = \frac{\sum_{i=1}^{N} t_{ts,i,r} \cdot w_{ts,i,r}^{SIM}}{\sum_{i=1}^{N} w_{ts,i,r}^{SIM}}. \tag{3.21}$$

The adjustment in the import mix is therefore driven by the relative domestic price changes at the tariff line level in the equation system (3.18)-(3.20). The impact of cutting notified tariffs on domestic prices is calculated thanks to a unique database (see section 3.5) and can be explained as follows. For each importing region, the import price is calculated as c.i.f. price plus applied tariff. If, and only if, after tariff cuts the import price falls below the domestic price level, then the domestic price is linearly reduced (in other words, the ratio between the domestic and import price plus applied tariff stays constant over time). This rule implies that tariff reductions only have an impact on domestic prices if the "water" in the applied tariffs is completely eroded. A unique database that includes domestic and c.i.f. prices at the 8-digits level enables TRIMAG to take into account the "water" in applied tariffs explicitly. The water in tariff is calculated as the difference between the c.i.f. import price plus the applied duty and the Swiss price. Assuming a lower Swiss domestic price then the tariff inclusive import price, the water indicates the "overprotective" part of the applied duty, i.e. the part that is in excess of what would be needed to maintain the difference between the domestic and the c.i.f. price. Under TRQ the water in tariff corresponds to the difference between the applied out-of-quota quota duty and the unit quota rent. Being able to estimate the "water" in tariffs is a significant advantage of TRIMAG over the TE aggregator where the domestic price is assumed to wedge away from world prices by the tariff height only. The expected impact on the domestic price are first calculated for both importing regions (EU and RW), and then aggregated according to the following possibilities: 1) import weighted average of the two regional import price reductions (no substitution is assumed between the import sources), 2) minimum regional import price reduction (perfect substitution between import sources, where cheaper imports are assumed to fully replace all other imports), or 3) a weighted combination of the previous two options. By considering that the EU is by far the biggest exporter of agricultural products to Switzerland, and that tariff reductions will be applied to EU imports only, option 2) is selected for our analysis.

With respect to the link to the CAPRI model, the aggregated in-quota and out-of-quota ad valorem tariff rates for beef are transferred directly to CAPRI. As the TRIMAG tariffs are ad valorem, any specific tariff rates (defined on a quantity basis) in CAPRI are converted to their AVE. The endogenous modelling of the TRQ system in CAPRI is kept, as in standard CAPRI applications, only the in-quota and out-of-quota rates are adjusted by TRIMAG.

3.4 Short description of the CAPRI modelling system

The following section provides a short description of the CAPRI modelling system used for the scenario analysis of the beef tariff dismantling scenarios. The focus is only on those aspects of CAPRI that are relevant for our simulation exercise; a more detailed description can be found e.g. in Britz and Witzke (2014).

The standard CAPRI model is a global comparative-static deterministic partial equilibrium model with a focus on European agriculture. Nevertheless, CAPRI includes a global market module covering the main agricultural and food commodities. The market module covers 77 countries or country aggregates in 40 trade blocks and about 50 products. The model follows the Armington approach for simulating bilateral trade flows, taking into account the price impacts of bilateral and multilateral trade policy instruments (including ad valorem and specific tariffs and TRQs). The market model consists of structurally identical template equations for all regions and commodities. Regional and commodity-wise specificities are expressed by the differences in parameterization. Supply and demand equations are consistent with microeconomic theory by imposing homogeneity and other curvature conditions during calibration. The supply of agricultural and feed compound sector are derived from a Normalized Quadratic profit function, while final demand is based on Generalized Leontief demand systems (Diewert, 1971). For Switzerland, in order to improve the empirical foundation of the supply response, the supply elasticities are based on estimates derived through sensitivity analyses carried out using the SWISSland agent based model (Möhring A., et al. 2016).

The standard CAPRI model has been applied extensively for trade-related policy impact assessment in the literature, (e.g. Burrell et al., 2011; Burrell et al., 2014; Pelikan et al., 2015). For the sake of this study, however, we extend the standard CAPRI model with pre-model tariff aggregation routines, both in calibration and simulation (Figure 3.1). In the case of the TE and fixed weight aggregators, model adjustments also included shifting the model-endogenous TRQ mechanism from CAPRI to the pre-model aggregation routines.

3.5 Application and scenario definitions

The meat sector is of great importance for the Swiss agriculture. In 2015, with about CHF 2 600 million, the beef production value represented slightly more than a quarter of the total Swiss agricultural production (BLW, 2016). The self-sufficiency rate for this product is around 80% rendering Switzerland a net importer. The meat sector in Switzerland is currently subject to a multilateral TRQ. Out-of-quota tariffs are very high. Given the extremely detailed definition of sub-quotas within the global TRQ, and also for the presence of a mixed method for their administration, the beef import regime is one of the most complex ones amongst Swiss products (Loi et al., 2016).

Both proposed tariff aggregation methodologies are implemented at the 8-digits level, therefore considering explicitly all registered transactions in the trade statistics and the full detail of the Swiss tariff schedule. Aggregating applied tariff rates under TRQs in an equilibrium framework faces the challenge that applied tariff rates and imported quantities are interdependent. Furthermore, assumptions on the unit quota rents are still unavoidable. Assuming a TRQ fill rate of 100%, which is typical for Swiss beef imports, the unit quota rent can be set theoretically to anywhere between the in-quota (preferential) and out-of-quota rates. However, the span between the in- and out-of-quota rates can be quite large especially when considering the beef commodity group in Switzerland. The TE aggregator determines the unit quota rent endogenously, relying on complementarity slackness conditions that mimic regime shifts between in- and out-of-quota tariffs at the tariff line level. Quota rents in the initial point still need to be assumed in order to perform the calibration of the TRQ equations. Instead, TRIMAG takes advantage of its detailed database and defines the unit quota rent as the difference between the domestic and the c.i.f. prices at the 8-digits level. The difference between the out-of-quota quota duty and this unit quota rent gives information on the amount of the overprotective part of the duty, or “water”.

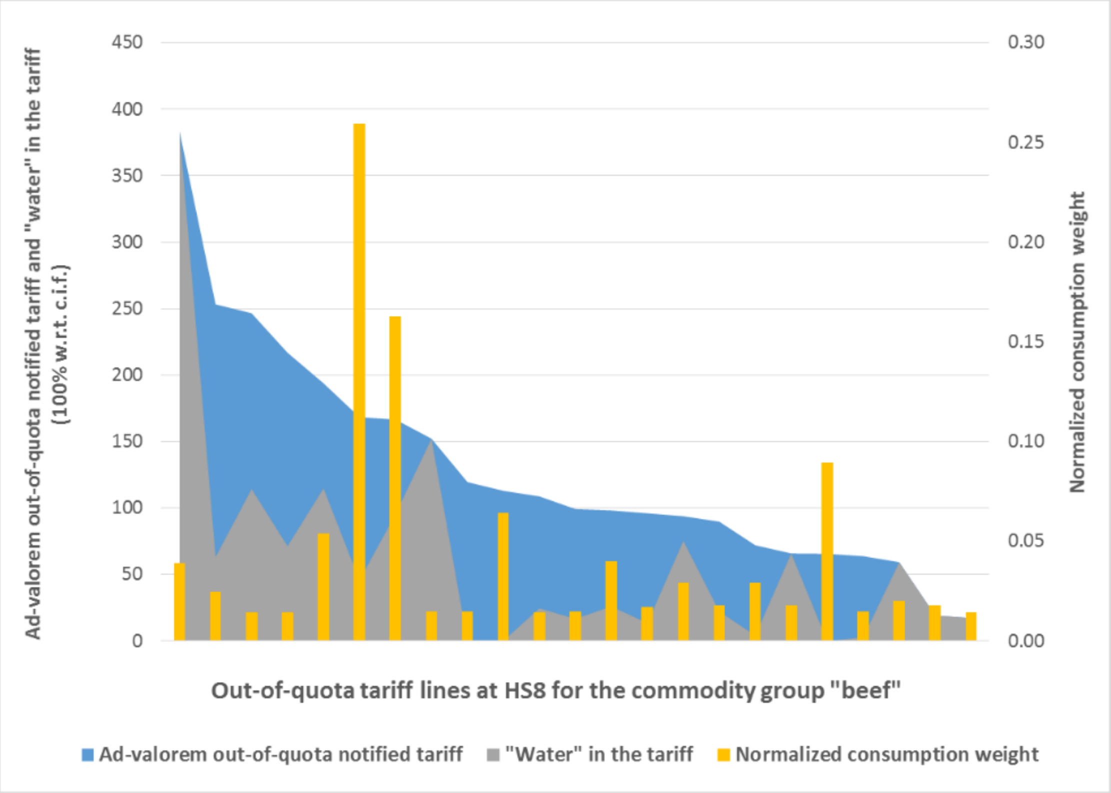
For the aggregate product “beef” there are 22 in-quota and 23 out-of-quota quota tariff lines (in the Swiss tariff schedule, in- and out-of-quota tariff lines do not necessarily have a one-to-one correspondence). This product group is very heterogeneous ranging from live animals to fresh or frozen carcasses, fresh or frozen meat boneless or with bones in, and offal. The multilateral TRQ No. 05 for red meat includes beef, horsemeat, sheep and goat meat. The total volume notified at the WTO is of 22.500 t. The biggest in-quota imports occur for beef that is further subdivided into various sub quotas. Out-of-quota quota tariffs are extremely high, and therefore imports mostly occur within the quota limit. For more details see also Loi et al., (2016).

In order to further ease the evaluation of the methodological improvements, we also calculate traditional fixed weight aggregate tariffs. More precisely, we opt for an import weighted aggregator that is quite standard in the literature, and that follows the approach of Bouet et al. (2008) for the calculation of applied tariff rates under TRQ: (i) if the fill rate is between 95% and 99%, the applied rate is an arithmetic average of the in-quota and out-of-quota rates; (ii) below a 95% fill rate the in-quota rate is taken and (iii) above 99% fill rate with the out-of-quota rate is calculated. As noted e.g. by Himics and Britz (2016), fixed weight aggregators set the unit quota rent arbitrarily and therefore lead to erroneous aggregate applied rates under TRQ. Nevertheless, it serves as a benchmark for the proposed aggregation methods.

We opt for a simple scenario setup in order to keep the comparison between the two proposed methodologies tractable. Note that, as the aggregate initial tariffs are already different using different aggregation approaches, one reference scenario (REF) for each approach have been developed. In our comparative static analysis trade liberalization impacts are always presented relative to their respective reference scenarios. The following two liberalization scenarios are implemented: SCEN_1, where a 50% tariff cut applies on all notified tariff lines at the 8-digits level (in-quota and out-of-quota) for the beef imports originating from the EU; SCEN_2, similar to SCEN_1, but where two out-of-quota tariff lines (0201.3099, fresh boneless beef meat and 0202.3099, frozen boneless beef meat) are exempted from the tariff cut. These two out-of-quota tariff lines are characterized by comparable specific tariff heights but different aggregation weights in the reference scenario, as well as different levels of “water” in the applied duties. The heterogeneity in tariff rates and tariff cuts as well as the presence of significant "water" in tariffs makes these scenarios particularly useful for evaluating the proposed tariff aggregators.

We expect that the three aggregation biases we discuss in this paper will be relevant for our scenarios. Firstly, aggregation weights for a product group are not uniformly distributed already in the reference scenario (for a distribution of tariff heights, “water” and aggregation weights see Figure 3.2). Therefore, the substitution effect at the tariff line level is expected to be significant. Secondly, although SCEN_1 assumes a homogenous (50%) tariff cut for all tariff lines, the changes in relative import prices is expected to be heterogeneous due to different “water” levels. Comparing TE and TRIMAG results in the following section sheds light on the importance of different levels of “water” in tariffs. Note here that, while TRIMAG takes into account “water” in both notified and applied tariffs explicitly, the TE aggregator follows a “price gap” approach and therefore is not able to explicitly consider the impact of the “water” in tariff on domestic price adjustments. Thirdly, explicitly considering the TRQ mechanism in the tariff aggregators is also crucial for the analysis on the beef sector. As the TRIMAG approach calculates aggregated in- and out-of-quota rates, it allows for an explicit TRQ function in the aggregated (CAPRI) model for beef. This is not the case for the other two aggregators, where TRQs are fully converted into an ad valorem tariff equivalent. We expect lower changes in Swiss beef imports in the TRIMAG case, due to the presence of the explicit TRQ function, which model-endogenously increases unit quota rents in parallel with the expansion in traded quantities.

Figure 3.2: TRIMAG calculated ad valorem out-of-quota notified tariffs, “water”, and aggregation weights for the reference mode in TRIMAG



Source: TRIMAG. Note: tariff lines are ordered according to tariff height.

3.6 Data and simulation results

This section reviews first the input data and then the simulation results for the proposed tariff aggregators. In the TE tariff aggregator, import values and quantities are from the Swiss-Impex database (Swiss-Impex, 2015) at 8-digits level; for the analysis we used average import volumes in 2009-2014. Exporter countries are mapped and potentially aggregated to the CAPRI regional list before setting up the equation system of the TE aggregator. Therefore the exporter-specific aggregate tariffs of equation (3.7) can be plugged in CAPRI directly. In the Swiss tariff schedule, in-quota/out-of-quota tariffs are registered under different tariff lines. In order to link that information to the TRQ equation system (3.9)-(3.12), out of quota tariffs are paired with their corresponding in-quota tariff lines. The TRQ equations are therefore defined for the merged (in total 22) TRQ lines for Swiss beef imports.

The same database is used to calculate the fixed weight aggregated tariffs. The crucial difference is that in the absence of an explicit demand system at the tariff line level, no substitution effects (no changes in aggregation weights) could be taken into account.

For the TRIMAG aggregator, the base year is defined as an average of the 2004-09 years for all 8-digits tariff lines of the Swiss tariff schedule. The data on bound and applied tariffs are included in the database. Imports values and quantities, as well as c.i.f. prices are differentiated by main origins (EU and RW[19]). Domestic Swiss prices (wholesale level) are also included at this very detailed level, enabling a precise calculation of the "water" in tariffs. For the simulation year, exogenous assumptions (exchange rate and medium term projections on agricultural markets) are also explicitly taken into account and further validated by market experts.

Aggregated beef tariffs in the corresponding reference scenarios already highlight differences in the aggregation approaches (Table 3.2). After TRIMAG calculates an aggregated in-quota rate of 15% and an aggregated out-of-quota rate of 145% pre-model, the final AVE of 142% is calculated for the aggregated beef commodity during the calibration of the whole CAPRI modelling system. As the AVE is close to the out-of-quota rate, a very strong import demand (high unit quota rent) is assumed. The 83% AVE for the TE aggregator is calculated fully pre-model, at the tariff line level, based solely on tariff line level data, including fill rates for the individual tariff lines. That results in a lower aggregated unit quota rent for beef in the REF scenario. The fixed weight aggregator calculates an initial tariff rate (99%) which is between the two previous approaches. As TRQs on most tariff lines are close to 100% filled, the fixed weight aggregator often sets the applied rate at the middle of the range between in- and out-of-quota rates.

Using fixed aggregation weights a 50% uniform tariff cut on all tariff lines (SCEN_1) translates into a 50% aggregated tariff cut in the aggregated tariff for EU beef imports. Having some tariff lines exempt from the cuts (SCEN_2) reduces the aggregate tariff cut to -46%. With both of our proposed aggregators we derive an aggregate tariff cut for EU beef products close to 50% in SCEN_1: -48% and -51% for respectively.

Only making two important tariff lines exempt from tariff cuts (SCEN_2) generates significant differences among the aggregation approaches in terms of the aggregated tariffs for EU beef

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[19] The aggregation of all non-EU partners into RW is due to the fact that more than 70% of the Swiss agricultural trade takes place with the EU (see www.agrarbericht.ch).

products. Consumers tend to substitute towards commodities with higher relative price drops, which in this case induce an adjustment in the consumption mix toward commodities with higher tariff content. Also the explicit TRQ functions adjust applied rates upward as imports expand; an effect totally missing from the traditional (fixed weight) approaches.

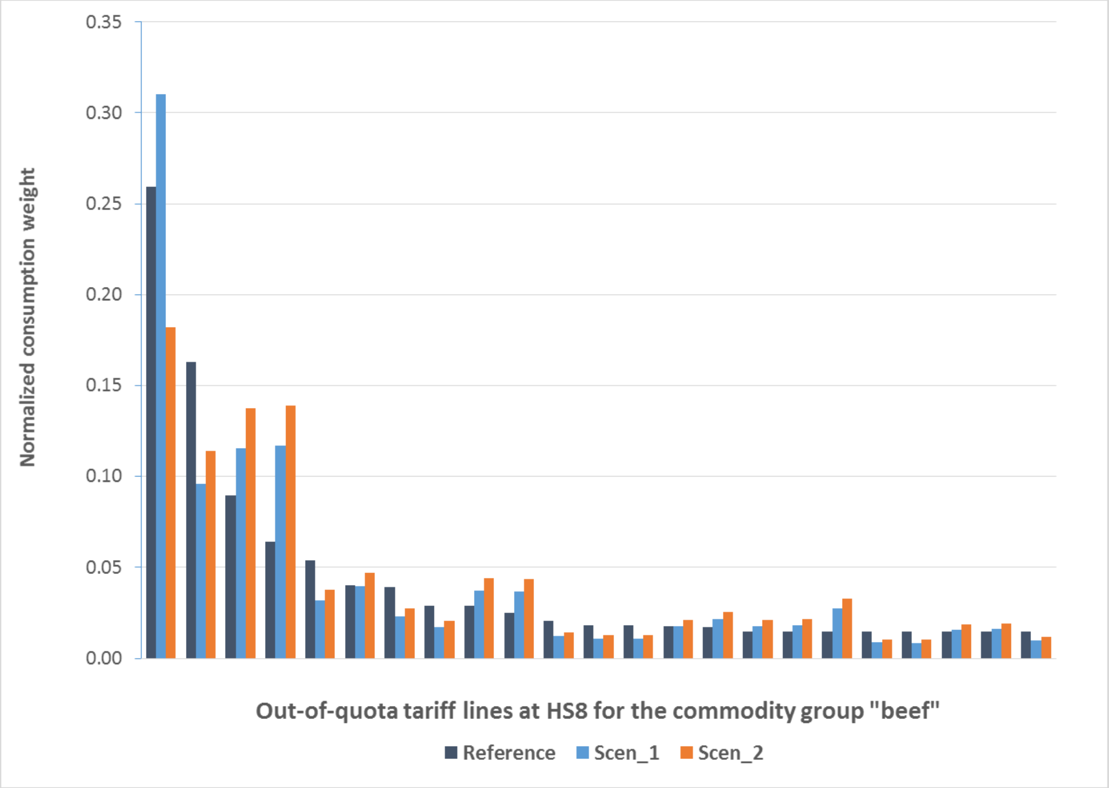
Table 3.2: Applied ad valorem equivalent tariffs and impacts on Swiss beef imports

	Fixed weight Aggregator					
	Aggregated Applied Ad valorem (%)			Import Volume (1000 t)		
From	REF	SCEN_1	SCEN_2	REF	SCEN_1	SCEN_2
EU 15	98.8	49.4 (-50%)	53.9 (-46%)	15.7	26.7 (70%)	25.5 (63%)
Brazil	109.0	109.0 (0%)	109.0 (0%)	2.0	0.6 (-69%)	0.7 (-65%)
Argentina	85.4	85.4 (0%)	85.4 (0%)	0.9	0.3 (-69%)	0.3 (-65%)
USA	40.9	40.9 (0%)	40.9 (0%)	0.6	0.2 (-69%)	0.2 (-65%)
	TE Aggregator					
	Aggregated Applied Ad valorem (%)			Import Volume (1000 t)		
From	REF	SCEN_1	SCEN_2	REF	SCEN_1	SCEN_2
EU 15	83.2	43.2 (-48%)	68.3 (-18%)	15.7	26.0 (65%)	19.1 (22%)
Brazil	157.8	157.8 (0%)	157.8 (0%)	2.0	0.7 (-62%)	1.4 (-27%)
Argentina	140.4	140.4 (0%)	140.4 (0%)	0.9	0.3 (-62%)	0.6 (-27%)
USA	67.2	67.2 (0%)	67.2 (0%)	0.6	0.2 (-62%)	0.4 (-27%)
	TRIMAG Aggregator					
	Aggregated Applied Ad valorem (%)			Import Volume (1000 t)		
From	REF	SCEN_1	SCEN_2	REF	SCEN_1	SCEN_2
EU 15	142.1	70.0 (-51%)	86.0 (-39%)	16.3	26.8 (64%)	23.7 (45%)
Brazil	142.1	85.4 (-40%)	98.5 (-31%)	2.1	2.0 (-2%)	2.0 (-2%)
Argentina	142.1	85.4 (-40%)	98.5 (-31%)	0.9	0.9 (-2%)	0.9 (-2%)
USA	142.1	85.4 (-40%)	98.5 (-31%)	0.6	0.6 (-2%)	0.6 (-2%)

Source: CAPRI simulation results.

The aggregate cuts in SCEN_2 are reduced substantially using our proposed approaches, unlike the relatively small decrease (from -50% to -46%) observed using the fixed weight aggregator. In the TE aggregator, the average tariff cut is only -18% for the EU-15 due to an important substitution effect towards the exempted tariff lines. The substitution effect is less pronounced using TRIMAG (the average cut in SCEN_2 is -39%) due to taking into account possible water in tariffs. Significant water in tariffs can reduce the impact on domestic prices and consequently on the substitution effect between tariff lines. The applied tariff rates reported for TRIMAG in Table 3.2 are marginal tariff rates. In both scenarios they coincide with the out-of-quota tariff rate, as the increasing imports push the TRQ regime to the out-of-quota situation. Another TRIMAG-specific result is the decline in the shadow price for non-EU bilateral TRQs, although it has little effect on the imported volumes given the relatively very low initial level of imports from non-EU countries. We also note that one of the exempted tariff lines (0201.3099) has a very high aggregation weight and therefore reduces the average tariff cut substantially, while the other tariff line (0202.3099) has a much lower weight and therefore almost no impact on the aggregated cuts (Figure 3.3).

Figure 3.3: TRIMAG calculated aggregation weights for the reference mode and the two scenarios



Source: TRIMAG. Note: aggregation weights are ordered according to their height in the reference mode.

Such a difference between tariff cuts in SCEN_1 vs. SCEN_2 is not present for the fixed weight aggregator. As individual applied rates are often set according to the simple rule of half the difference between in- and out-of-quota rates, making only two tariff lines exempt of the cuts has only limited impact on the aggregate tariff rate. An important shortcoming of traditional aggregation techniques can be observed: the heterogeneity we introduced in tariff cuts in SCEN_2 is only partially impacting the aggregated tariff rates.

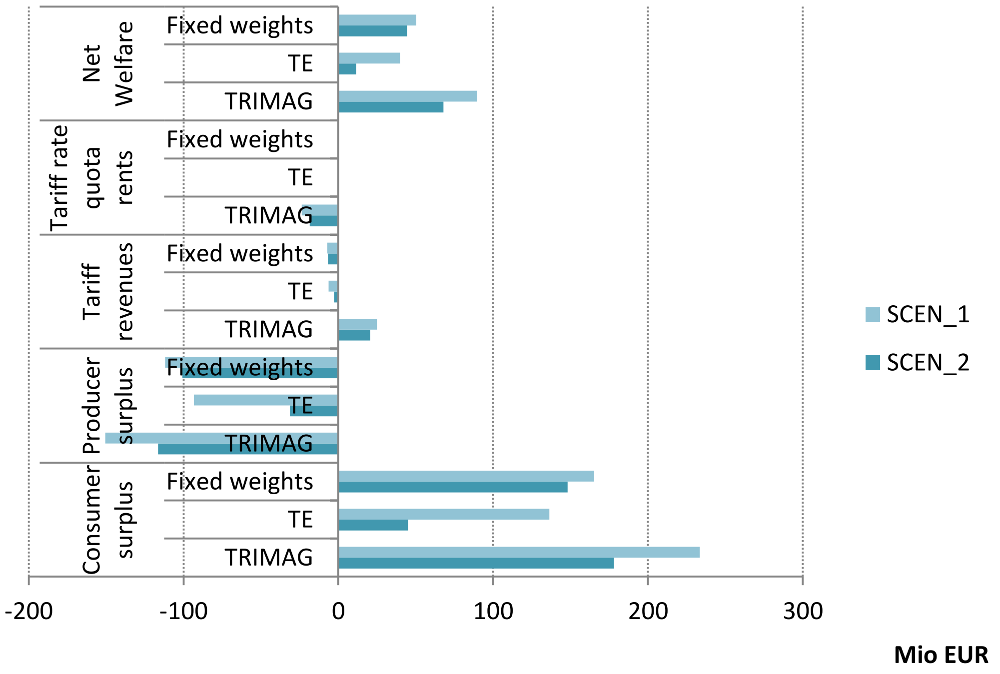
As the aggregate tariff cuts in SCEN_2 are significantly smaller, in relative terms, for the proposed aggregation approaches we also expect significant differences in simulated trade impacts. Indeed, the EU (as main player on the Swiss beef market) increases exports by 65% in SCEN_1 and by 22% in

SCEN_2 when using the TE aggregator; whereas using TRIMAG imports from the EU increase by 64% in SCEN_1 and by 45% in SCEN_2 (Table 3.2). The fixed weight aggregator delivers only small differences in simulated trade impacts between the two scenarios.

The equivalent variation measure of consumer welfare increases in all scenarios and under all aggregation methodologies (Figure 3.4). This is a standard result for tariff reduction in Armington models, and is due to decreasing consumer prices for beef. Conversely, a decrease in the producer surplus can be observed, as lower import prices are transmitted to domestic beef producers. There are, however, key differences in the magnitude of net welfare increases. With the TRIMAG approach we simulated significantly higher welfare gains from the tariff liberalization. The substitution effect and the more precise price transmission of tariff cuts to domestic prices due to modelling "water" in tariffs and TRQ mechanisms explicitly all increase simulated welfare gains. Simulated net welfare gains are the lowest with the TE approach due to the lowest aggregate tariff cuts, especially in SCEN_2.

Tariff revenue impacts are different when using an ad valorem equivalent approach (fixed weight and TE aggregators) versus an explicit TRQ function approach (TRIMAG). Using a simple ad valorem equivalent tariff the scenario impacts are negative, because the increase in beef imports cannot compensate for the decrease in tariff rates. But with an explicit TRQ function in place, such in the case of implementing TRIMAG aggregate tariffs in CAPRI, the increase in imports pushes the TRQ fill rate well over 100%, and therefore for a large portion of beef imports the higher out-of-quota duty applies. That generates an increase in tariff revenues in both scenarios, even though the out-of-quota rates are lower than those of the reference scenario.

Figure 3.4: Welfare impacts for the beef sector in Switzerland (changes compared to REF scenario).



Source: CAPRI simulation results.

The impact on TRQ rents is negative using the TRIMAG aggregator, as the increasing beef imports cannot compensate for the decreasing unit quota rents under TRQ. As the Swiss beef TRQs are fully converted into an ad valorem tariff rate with the other two aggregation approaches, no quota rents are reported.

3.7 Conclusions

In this paper we develop and compare two multipurpose tariff aggregation techniques, the TE and TRIMAG aggregators that address important sources of biases in applied trade modelling: substitution effects at the tariff line, “water” in tariffs and TRQs. Both aggregators are applied and compared relying on a common set of beef tariff dismantling scenarios in Switzerland. The comparison is also enriched by adding a fixed weight aggregator in order to compare the performance of the proposed multipurpose aggregators against a standard tariff aggregator. The beef sector is particularly suited to assess these tariff aggregators since: a) the number of beef tariff lines is sufficiently large to render substitution effects among the different lines meaningful; b) the beef tariff lines are characterized by different levels of “water” in the applied duty; c) beef is in Switzerland regulated by a complex system of import TRQs.

Both the TE and TRIMAG aggregators are implemented as pre-model aggregation modules in a large-scale PE model (CAPRI). Our analysis is limited to the agricultural sector with no feedback effects from other sectors of the economy. Linking the proposed aggregation techniques to CAPRI does not require significant changes in the original model. As the tariff aggregation calculations are made pre-model, only a single ad valorem equivalent measure[20] of various border protection instruments (tariffs, TRQs, etc.) enters the original PE model. Thus the trade policy representation in the original equilibrium model can be simplified by shifting various border protection instruments into a pre-model tariff aggregation module. This has obvious numerical advantages compared to a fully consistent solution that would extend the original model with PE modules working at the tariff line level (e.g. Grant et al., 2007, Narayanan et al., 2010). Given that the tariff aggregation approaches we propose only simulate demand side adjustments, they are relatively easy to set up and solve numerically, and detailed trade statistics and policy data are available to parameterize the pre-model aggregation.

Our results confirm that traditional (fixed weight) aggregators, without appropriately taking into account substitution effects, "water" in the tariff lines and an endogenous TRQ modelling, tend to lead to biased estimates for the gains from trade liberalization, both in terms of the impact on trade flows and welfare (Anderson 2009, Laborde et al. 2017). We also find that the difference between the fixed weight aggregator and those proposed to correct for important aggregation biases is particularly large when trade liberalization scenarios introduce large variation in tariff cuts. We therefore provide further empirical evidence that the use of fixed weight aggregators is not recommended in case of large heterogeneity in tariffs structures. This is not only true when the variability of the initial tariffs is high (Laborde et al. 2017), but also in case trade liberalization is expected to increase tariff dispersion to a large extent. Thus the proposed tariff aggregation

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[20] In an attempt to use fully welfare consistent aggregation in the general equilibrium framework, Anderson (2009) has to modify the original balance of trade condition by introducing a combination of two tariff aggregators. Himics and Britz (2016) need to increase complexity in the trade balance constraint in order to take into account TRQ rents and the geographical composition of exporters, combining in total six different tariff aggregators.

methodologies can significantly improve the quality of ex-ante policy impact assessments, without a heavy burden of modifying core model structures. The fact that both the TE and the TRIMAG aggregators can be implemented as pre-model aggregation modules without significantly altering existing model structures represents a clear potential for their more wide-spread use in applied trade modelling.

Some caveats to the proposed approaches, however, must be highlighted. A serious shortcoming of the approaches is that the impact of changing trade policies on domestic supply is neglected. In fact the TRIMAG and TE aggregators only account for the consumption gains from trade but not for any production or specialization gains. Whether this is an acceptable restriction remains case specific. In our empirical application, the potential consumption gains from liberalizing the beef trade largely outweigh the losses linked to domestic production, and therefore the assumption is viable. The assumption that trade policies have no impact on domestic producer prices is also present in empirical applications of welfare consistent tariff aggregation (Bach and Martin 2001, Anderson 2009 or Himics and Britz 2016).

The proposed techniques are also rather data intensive, requiring information that might not yet be available at the global scale, such as domestic consumer prices at the tariff line level. The extension of the proposed aggregation methods to all sectors and regions of state-of-the art, large scale CGE models thus requires further advances in database developments.

3.8 References

Anderson, J.E. (2009). Consistent trade policy aggregation. International Economic Review, 50: 903–927.

Anderson, J.E. and Neary, J.P. (2005). Measuring the Restrictiveness of International Trade Policy. The MIT Press, Cambridge, Massachusetts.

Anderson, J.E., Wincoop, E. van, 2004. Trade Costs. J. Econ. Lit. 42, 691–751.

Bchir, M.H., Jean, S., Laborde, D., 2006. Binding Overhang and Tariff-Cutting Formulas. Review of World Economics / Weltwirtschaftliches Archiv 142, 207–232.

Bach, C.F. and Martin, W. (2001). Would the right tariff aggregator for policy analysis please stand up? Journal of Policy Modelling, 23: 621–635.

Beshkar, M., Bond, E.W., Rho, Y., 2015. Tariff binding and overhang: Theory and evidence. J. Int. Econ. 97, 1–13. doi:10.1016/j.jinteco.2015.04.004

Bouet, A., Decreux, Y., Fontagne, L., Jean, S. and Laborde, D. (2008). Assessing applied protection across the World. Review of International Economics, 16: 850–863.

Britz W. and van der Mensbrugghe D (2016). Reducing unwanted consequences of aggregation in large-scale economic models - A systematic empirical evaluation with the GTAP model. Economic Modelling, 2016, vol. 59, issue C, 463-472

Britz W. and Witzke H.P. (2014). CAPRI Model Documentation 2014. Retrieved on September 26, 2014 at: http://www.capri-model.org/docs/capri_documentation.pdf

Bundesamt für Landwirtschaft (BLW) (2016). Agrarbericht 2016, Bundesamt für Landwirtschaft (BLW), Bern. Retrieved on January 13, 2016 at: www.agrarbericht.ch.

Burrell, A., Ferrari, E., Gonzalez Mellado, A., Himics, M., Michalek, J., Shrestha, S., Van Doorslaer, B., 2011. Potential EU-Mercosur Free Trade Agreement: Impact Assessment (No. EUR 25011 EN), JRC Reference Reports. European Commission, Joint Research Centre.

Burrell, A., Himics, M., Van Doorslaer, B., Ciaian, P., Shrestha, S., 2014. EU sugar policy: A sweet transition after 2015? (No. EUR 26530 EN), JRC Scientific and Policy Reports. JRC European Commission.

Diewert, W.E., 1971. An Application of the Shephard Duality Theorem: A Generalized Leontief Production Function. J. Polit. Econ. 79, 481–507

Egger, P., Francois, J., Manchin, M., Nelson, D., 2015. Non-tariff barriers, integration and the transatlantic economy. Econ. Policy 30, 539–584. doi:10.1093/epolic/eiv008

Francois, J., Van Meijl, H., Van Tongeren, F., 2005. Trade liberalization in the Doha Development Round. Econ. Policy 20, 349–391. doi:10.1111/j.1468-0327.2005.00141.x

French, S., 2016. The composition of trade flows and the aggregate effects of trade barriers. J. Int. Econ. 98, 114–137. doi:10.1016/j.jinteco.2015.10.004

Grant, J.H., Hertel, T.W. and Rutherford, T.F. (2007). Tariff line analysis of U.S. and international dairy protection. Agricultural Economics, 37: 271–280.

de Gorter, H. and Kliauga, E. (2006). Reducing tariffs versus expanding tariff rate quotas. In Anderson, K, and Martin, W. (eds). Agricultural Trade Reform and the Doha Development Agenda. Basingstoke, U.K.: Palgrave Macmillan; Washington, DC: World Bank.

Himics, M. and Britz, W. (2016). Flexible and welfare-consistent tariff aggregation over exporter regions. Economic Modelling, 53: 375–387.

Laborde, D., Martin, W., van der Mensbrugghe, D., 2017. Measuring the Impacts of Global Trade Reform with Optimal Aggregators of Distortions. Review of International Economics 25, 403–425. doi:10.1111/roie.12271

Listorti, G., Tonini, A., Kempen, M., & Adenäuer, M. (2013). How to implement WTO scenarios in simulation models: linking the TRIMAG tariff aggregation tool to CAPRI. 135th EAAE Seminar, Challenges for the Global Agricultural Trade Regime after Doha, Belgrade, Serbia, 28-30 August.

Loi A., Esposti R., Gentile M. et al. (2016). Policy Evaluation of Tariff Rate Quotas. Report mandated by the Swiss Federal Office of Agriculture. Areté srl, Bologna.

Möhring A., Mack G., Zimmermann A., Ferjani A., Schmidt A., Mann S. (2016) Agent-based modeling on a national scale – Experiences from SWISSland. Agroscope Science 30: 1-56.

Muhammad, A, D'Souza A., Meade B., Micha R., and Mozaffarian D. (2017). The Influence of Income and Prices on Global Dietary Patterns by Country, Age, and Gender, ERR-225, U.S. Department of Agriculture, Economic Research Service, February 2017.

Narayanan, B.G., Hertel, T.W. and Horridge, J.M. (2010). Disaggregated data and trade policy analysis: The value of linking partial and general equilibrium models. Economic Modelling 27: 755–766.

Pelikan, J., Britz, W., Hertel, T.W., 2015. Green Light for Green Agricultural Policies? An Analysis at Regional and Global Scales. J. Agric. Econ. 66, 1–19. doi:10.1111/1477-9552.12065

Philippidis, G., Sanjuán, A.I., 2007. An Analysis of Mercosur's Regional Trading Arrangements. World Econ. 30, 504–531. doi:10.1111/j.1467-9701.2007.01002.x

Swiss-Impex, (2015). "Swiss-Impex Data for 2015." Accessed 22 January 2016. https://www.swiss-impex.admin.ch/index.xhtml.

World Trade Organization (2012). Tariff Quota Administration Methods and Fill Rates 2002–2011

Chapter 4: Does the current trade liberalization agenda contribute to greenhouse gas emission mitigation in agriculture?[21]

Abstract

This paper contributes to the literature on the trade liberalization – climate change nexus by investigating the impact of the current free trade agenda of the European Union (EU) on the effectiveness of a possible greenhouse gas (GHG) reduction policy for its agricultural sector. For the analysis we implement scenarios with a carbon tax on non-CO2 emissions and trade liberalization both individually and combined in CAPRI, a global partial equilibrium model for agriculture. Scenario results indicate that the simulated trade liberalization by itself has only modest effects on agricultural GHG emissions by 2030. Pricing agricultural non-CO2 emissions in the EU triggers the adoption of mitigation technologies, which contributes to emission reductions. Emission leakage, however, partially offsets the EU emission savings as production increases in less emission-efficient regions in the world. The combination of agricultural trade liberalization and carbon pricing increases emission leakage and, therefore, further undermines global mitigation gains. Our results hinge on the key assumptions that future trade agreements between non-EU countries are not considered and that the climate actions are limited to the EU only. Despite these limitations we conclude that, from a global GHG mitigation perspective, trade agreements should address emission leakage, for instance by being conditional on participating nations adopting measures directed towards GHG mitigation.

Keywords: climate change, agriculture, trade, emission leakage, European Union

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[21] This chapter has been published as Himics, M., Fellmann, T., Barreiro-Hurlé, J., Witzke, H.-P., Pérez Domínguez, I., Jansson, T., Weiss, F., (2018). Does the current trade liberalization agenda contribute to greenhouse gas emission mitigation in agriculture? Food Policy 76, 120–129. doi:10.1016/j.foodpol.2018.01.011

4.1 Introduction

The Paris Agreement on Climate Change legally entered into force on 4 November 2016. Specific modalities and procedures still have to be negotiated, but in general the Paris Agreement requires all Parties to take on ambitious efforts to mitigate GHG emissions and combat climate change through "nationally determined contributions" (NDCs). Enhanced international efforts to mitigate GHG emissions coincide with an increase in the number and scale of regional trade agreements. As the Doha Round of WTO negotiations stalls, large economies try to boost their economic growth by engaging in regional trade agreements with their main partners. Examples of such behavior include the Trans-Pacific Partnership (TPP) and the Transatlantic Trade and Investment Partnership (TTIP) negotiations, each covering a large share of global trade in goods and services. The EU follows a similar strategy and is increasingly engaged in regional trade negotiations (e.g. with Canada, USA or the Mercosur countries).

The parallel development of trade liberalization and GHG reduction policies raises the question on their interplay. Whether a continuous liberalization of the agri-food markets contributes positively or negatively to emission mitigation efforts is a complex empirical question. The theoretical framework of environmental effects of trade-liberalization (Grossman and Krueger 1991) breaks down trade liberalization impacts on GHG emissions to the following three components: (1) the scale effect, i.e. liberalized trade boosts production and consumption, ceteris paribus increasing global GHG emissions; (2) the composition effect, i.e. facilitating trade also changes the composition of the goods produced and consumed, hence the net effect on global emissions depends on the emission intensity of the industries that gain from trade liberalization; and (3) the technique effect, i.e. liberalizing trade increases technological development and technology transfer unequivocally leading to a reduction in global emissions by promoting more emission-efficient technologies. Whether the net environmental impact of these three effects is positive or negative requires a quantitative analysis that weights the individual effects. Existing empirical evidence is controversial regarding the relative weight of each of the effects. Overall results move between two extremes: (i) trade liberalization and globalization leads to environmental degradation, especially in developing countries, and (ii) more liberalized trade leads to increased economic growth with positive spill-over effects on the environment (Copeland and Taylor 2004; Wiedmann et al. 2007; Peters and Hertwich 2008; Huang et al. 2011; Peters et al. 2011). In any case, the mixed existing empirical evidence on the net aggregated effect of trade on global emissions hints towards the case specificity of impacts.

Against this background, this paper contributes to the debate by providing a detailed analysis on how trade liberalization agreements may affect global GHG mitigation efforts for a specific sector (agriculture) and a specific country-group (the EU) with a highly developed economic and policy environment. Accordingly, the main research question we pose is: How does trade liberalization impact the effectiveness of GHG policies in the EU agricultural sector? Addressing this question, we also discuss if, and to what extent, trade liberalization shifts EU emissions to trade partners and other third countries or vice versa, and what the net impact on global emissions is. More specifically, we investigate this issue focusing on the impact of the agricultural provisions of the regional Free Trade Agreements (FTA) currently under negotiation between the EU and 3rd parties (including TTIP and EU-Mercosur), and a (still hypothetical) policy aiming at reducing (non-CO_2) GHG emissions in EU agriculture enforced by means of a carbon tax[22].

The choice of the agricultural sector as the focus of our interest is motivated by its importance in non-CO_2 (methane and nitrous oxide) GHG emissions, and by its important role in global food security. As key results we present production and GHG emission effects in the EU and globally, quantifying also emission leakage of trade liberalization when implemented in isolation or combined with climate policy. More specifically, we compare three scenarios against a business as usual reference for 2030. First we show how trade liberalization alone affects production and emissions, second we show how production and emissions are affected by a unilateral carbon tax for non-CO_2 emissions of EU agriculture, and last we show how the combination of the two adds up.

4.2 Methodology

For the analysis, we use the CAPRI (Common Agricultural Policy Regional Impact Analysis) modelling system (Britz and Witzke 2014). CAPRI is a large-scale, comparative static, partial equilibrium model focusing on agriculture and the primary processing sectors. CAPRI links a set of mathematical programming models of the EU regional agricultural supply to a global market model for agricultural commodities. The regional supply models follow a Positive Mathematical Programming (PMP) approach for simulating the profit maximizing behavior of representative farms for all EU regions. The regional supply models are linked with a sequential calibration approach to a global multi-commodity model of the agricultural markets. International trade in the market model is implemented following the Armington assumption (Armington, 1969), i.e. imported goods are differentiated by place of origin, and consumer preferences for import demand are calibrated to a benchmark dataset (Britz and Witzke 2014).

The standard market module in CAPRI also includes explicit Tariff Rate Quota (TRQ) functions. In this paper, however, the TRQ functions are converted into ad-valorem equivalent (AVE) tariff rates in order to simplify the scenario assumption. Representing the TRQs with their AVE equivalent tariff rates enables us to simply cut them by a given percentage, without going into assumptions on possible quota expansions or changes in in-quota or out-of-quota tariff rates. The drawback of the AVE representation of TRQs is that it might magnify trade liberalization impacts, as reaching the quota threshold does not anymore imply an immediate increase in tariff rates in the model (Himics and Britz 2016).

With regard to GHG accounting, CAPRI endogenously calculates EU agricultural GHG emissions for nitrous oxide and methane based on the inputs and outputs of production activities. Following the IPCC guidelines (IPCC 2006), a Tier 2 approach is used for the calculation of activity-based emission factors, but where the respective information is missing a Tier 1 approach is applied (e.g. rice cultivation). Several specific technological (i.e. technical and management-based) GHG mitigation options for EU agriculture are considered, focusing on technological options that are already available or will likely be available at the simulation year 2030. Some of them are already used in EU agriculture (e.g. precision farming) but there is ample room for expansion to a much larger number of farms or production activities. The 14 mitigation technological options listed in Table 4.1 have

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[22] A carbon tax refers to a tax attributed to a unit of emissions expressed in CO_2 equivalents

been specifically considered for this paper and can be applied by EU farmers (for a detailed description of each technology see Pérez Domínguez et al. (2016).

Table 4.1: Technological GHG mitigation options available for adoption by EU farmers

Sector	**Technological mitigation options**
Livestock	Anaerobic digestion at farm scale, Low nitrogen feed, Linseed as feed additive, Nitrate as feed additive, Vaccination against methanogenic bacteria in the rumen, and specific breeding programs to increase (i) milk yields of dairy cows and (ii) ruminant feed efficiency
Crops	Precision farming, Variable Rate Technology, Better timing of fertilization, Nitrification inhibitors, Rice measures, Fallowing histosols (organic soils), Increasing legume share on temporary grassland

The underlying assumptions on implementation costs, cost savings, mitigation potential of the modelled technological mitigation options are mainly taken from the Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS) database (GAINS 2013, 2015; Höglund-Isaksson et al. 2013, 2016), and information collected within the AnimalChange project (Mottet et al. 2015). The level of production activities and the use of mitigation technologies are constrained by various factors, including land availability, fertilization requirements of the cropping systems versus organic nutrient availability, feed requirements in terms of dry matter, net energy, protein, and fiber for each animal. Moreover, production activities and decision making are also influenced by agricultural and environmental policy restrictions. A detailed description of the general calculation of agricultural emission inventories in CAPRI is given in Pérez Domínguez (2006), Leip et al. (2010) and Pérez Domínguez et al. (2012), and detailed description of the modelling approach related to the technological GHG mitigation options is presented in Van Doorslaer et al. (2015), Pérez Domínguez et al. (2016) and Fellmann et al. (2017).

Two additional issues are worth mentioning. First, the calculation of emissions is not homogenous between the EU and the rest of the world. While the emissions of EU agriculture are calculated directly based on the IPCC guidelines on a per activity basis in the CAPRI supply model, GHG emissions for the rest of the world are estimated on a commodity basis (i.e. per kg of product) in the market model of CAPRI. Second, and linked to the different calculation approach, in previous analyses non-EU emission intensities were purely based on historic emission and production data from FAOSTAT. This did not allow the integration of technical trends, e.g. improved emission efficiency over time. As the projection year for our analysis is 2030, neglecting trends in emission intensities in non-EU countries could lead to an overestimation of emission leakage (Barreiro-Hurle et al. 2016). GHG emission intensity improvements in the rest of the world could be a result of climate or non-climate related developments. Improvements could, for example, come of developed countries allocating climate funding to the adoption of GHG mitigation technology or as a consequence of GHG mitigation policies being implemented and subsidized in non-EU regions. Additionally, emission mitigation may also spread irrespectively of climate change concerns, for example if fertilizer efficiency improves or if anaerobic digestion plants are installed for purely economic reasons. Global emission trends could also imply a deterioration of efficiency over time due to composition effects.[23] To incorporate the possibility of emission intensity changes over time, trend functions are estimated for the emission intensities in the rest of the world using IPCC Tier 1 coefficients as prior information within a robust Bayesian estimation framework, combining data on production quantities and emission inventories from FAOSTAT (for more information on the approach see Jansson et al. 2010, 2014; Pérez Domínguez et al. 2016).

4.3 Scenario assumptions

Three policy scenarios are compared to a business as usual scenario (Reference): (i) a scenario that assumes an ambitious EU trade agenda to be fulfilled by 2030 (FTA scenario), (ii) a scenario for EU agriculture where a carbon tax of 50 EUR/t CO_2 equivalents is applied to non-CO_2 (i.e. methane and nitrous oxide) emissions of EU agricultural activities (EU Carbon Tax scenario), and (iii) a combination of the two. With the three scenarios we aim to disentangle the economic and environmental effects of trade liberalization and emission reduction policies, and shed some light on their interaction (Combined scenario). The simulation year for all scenarios is 2030 and in all scenarios farmers can voluntarily adopt technological mitigation options. The uptake of the mitigation technologies is driven by the model's profit maximization framework, and therefore farmers will only adopt the technologies if this improves farmers' competitiveness by reducing production costs. That may happen, for example, after the introduction of a carbon tax, which links the GHG emissions involved in the production of commodities to production costs.

Reference scenario 2030

The reference scenario assumes status quo policy as based on the information available mid-2016 (e.g., abolishing the EU milk and sugar quotas) and only considers agricultural, environmental and trade policies that are already ratified. The reference scenario is calibrated to the European Commission’s outlook for agricultural markets and income (European Commission 2015), which itself is based on the OECD-FAO (2015) agricultural market outlook and gives medium-term projections up to the year 2025 in a consistent framework, using also external sources for the assumptions on macroeconomic developments (like GDP growth, exchange rates, world oil prices, and population growth). As the projection year for our analysis is 2030, we extrapolated and supplemented the European Commission’s projections with other information to arrive at the CAPRI reference scenario for the year 2030. A detailed description and discussion of the CAPRI calibration process is given in Himics et al. (2014).

FTA scenario

As the WTO negotiations seem to be stalled, the EU is actively seeking to engage in regional (bilateral) FTAs with the aim to boost economic growth. The EU's current trade agenda is filled with ongoing trade negotiations with its main trade partners and with countries in key geopolitical positions. In this paper we focus on those trade deals that are already under negotiation or likely to be negotiated in the mid-term. More precisely we take into account (i) two recently concluded but not yet adapted FTAs with Canada and Vietnam; (ii) major ongoing trade negotiations with the USA,

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[23] For example: Assume that production of beef in one country is represented by a single value, but in reality production takes place both in dairy systems in one part of the country and with dedicated beef breeds in another. If the relative weights of those systems in overall beef production would change, the average emission intensity of “beef” would change too.

the Mercosur countries, Japan, Thailand, the Philippines and Indonesia; (iii) two FTAs with Australia and New-Zealand, which are likely to be initiated in the short-term.

The varying roles agricultural policy plays in the different countries as well as food security and food safety issues related to foreign food commodities often make agriculture a stumbling block of trade negotiations. Although tariffs on traded goods generally have been decreasing in the last decade, tariffs and other border protection instruments on agri-food commodities are still relatively high. As concluded tariff schemes are not yet available for most of the FTAs considered, we apply a simplified and rather ambitious assumption on tariff reduction: full elimination of tariffs for most (non-sensitive) agricultural commodities and a 50% (partial) tariff cut for the rest of the products. The selection of sensitive products follows the approach of Boulanger et al. (2016), and it is based on expert judgment supplemented by a selection algorithm focusing on foregone tariff revenues[24].

The agricultural sector is specifically subject to a multitude of sanitary and food safety regulations that often act as non-tariff barriers (NTMs) to trade. Although those NTMs are significant, we did not include the potential reduction of NTMs in our analysis, lacking an adequate database at the global scale with a detailed coverage of agri-food trade. In addition, Armington trade models, such as CAPRI, are not able to simulate emerging trade flows (those that currently are not observed but which are likely to become significant after trade liberalization). Both the lack of NTMs and the zero trade flow issue related to the Armington trade specification imply a possible underestimation of the trade liberalization impacts (Philippidis et al. 2013, 2014). On the other hand, the EU's trade agenda is modelled to be fulfilled in isolation, i.e. further trade agreements excluding the EU are not considered. This assumption probably leads to an overestimation of the efficiency of EU trade liberalization, as countervailing regional FTAs, or a future WTO agreement would likely lower the EU gains from this liberalized trade agenda.

EU Carbon Tax scenario

With respect to GHG emission mitigation obligations, the EU agricultural sector is currently included under the Effort Sharing Decision (ESD) within the "2020 Climate and Energy Package" of the EU (European Council 2009). In this ESD, the EU member states have GHG emission mitigation targets that are specific to individual countries but not to individual sectors. Up to now no explicit policy measures have been implemented to directly force the agriculture sector to reduce GHG emissions. This holds even though there are a number of measures targeting agriculture with objectives that also have climate benefits, such as the EU's Nitrates directive. However, recent scenario analyses indicate that reductions in agricultural emissions will be important to achieve global climate goals of limiting warming to 1.5 or 2 degrees Celsius above pre-industrial levels (Gernaat et al. 2015; Wollenberg et al. 2016). In this context the Paris Agreement puts the agricultural sector back on the agenda of emission mitigation. In this paper we investigate the possible impacts of a carbon tax to be put in place for agricultural non-CO_2 emissions at EU level. We therefore put a tax of 50 EUR/t CO_2 equivalents on methane and nitrous oxide emissions on EU agricultural activities.

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[24] The selection of sensitive products has been carried out based on trade statistics at the tariff line level (HS6). The FTA scenario results in 98.5% of the tariff lines fully liberalized while the remaining 1.5% are subject to the reduced tariff cuts.

Combined scenario

To measure possible interaction effects between trade and climate policies, we also construct a scenario combining the two policy options: 50 EUR/t CO_2 equivalents tax on agricultural non-CO_2 emissions in the EU while at the same time taking into account a successful EU bilateral trade agenda. In section 4.5 the robustness of the Combined scenario is tested by varying the carbon tax level and the ambition of the EU's trade agenda.

4.4 Scenario results

In the following we concentrate on some key results with respect to EU production and related GHG emissions, and then quantify the impacts of the scenarios on global emissions. All scenario results are compared relative to the reference scenario in 2030.

A successful completion of the EU's trade agenda alone already affects significantly the EU's agricultural non-CO_2 GHG emissions, as in the FTA scenario emissions from agriculture are reduced by –1.6% in the EU. The imposed carbon tax on EU agricultural non-CO_2 emissions achieves a much larger reduction of –9.5%, while a combination of the two policies further decreases agricultural emissions by an additional percentage point to –10.7%.

The positive environmental impacts in the FTA scenario are mostly due to a reallocation effect of domestic agricultural supply in the EU to more competitive non-EU producers, i.e. the substitution of own domestic production with imports. Utilized agricultural area (UAA) in the EU is reduced significantly by almost 0.7 million ha, mainly due to a 6% decrease in cereals production. In parallel, set aside area and fallow land increases by almost 11%, thus further reducing arable land. The decrease in UAA and cereals production is accompanied by a 2% decrease in total nitrogen fertilizer application, which is a major source of agricultural nitrous oxide emissions. The EU beef meat herd, a main contributor of methane emissions from agriculture, is also decreasing by 2.4%, leading to a decrease in beef production of 1.6% (Figure 4.1). While EU poultry meat production is also decreasing by 2.6%, pork meat production slightly increases by 0.5%, however, the impact of these production developments on EU GHG emissions are minor as the emission intensity of pork and poultry is rather low compared to beef production activities.

The negative supply effects of introducing a carbon tax on non-CO_2 emissions from EU agriculture are also focused on the same sectors. However, as livestock production is more emission-intensive than crop production, the livestock sector is considerably more affected in the EU Carbon Tax scenario and the crop sector is less negatively affected than in the FTA scenario. Nonetheless, UAA is decreasing by 0.2 million ha in the EU Carbon tax scenario, and set aside and fallow land increases by almost 25%. Cereals production decreases by 2.3% compared to the reference scenario. Adjustments in livestock production are dominated by a reduction in ruminant herd sizes, with a -5.5% decrease in the number of animals linked to beef production and a -2.8% decrease in herd sizes of sheep and goat fattening, resulting the in meat supply decreases of 3% and 2.7%, respectively.

In a nutshell, in isolation both liberalizing trade and imposing a carbon tax reduces GHG emissions in the EU. However, while trade liberalization affects more EU crop production and related emissions, the carbon tax on EU agricultural non-CO_2 emissions impacts more on the livestock sector. The decrease in GHG emissions in the Combined scenario is basically achieved by an accumulation of the supply effects observed in the EU Carbon Tax and FTA scenarios. Accordingly, the impacts in the crop sector are generally more driven by the FTA and changes in the livestock sector more by the EU Carbon Tax. As a result, UAA declines by almost 1.6 million ha, cereals production decreases by 8% and set aside and fallow land increase by more than 32%. The EU beef cattle herd drops by almost 9%, leading to a decrease in beef production of 5%, whereas animal numbers and production of sheep and goat meat decline by 4.5%.

Figure 4.1: Percentage change in EU agricultural supply compared to the reference scenario (2030)

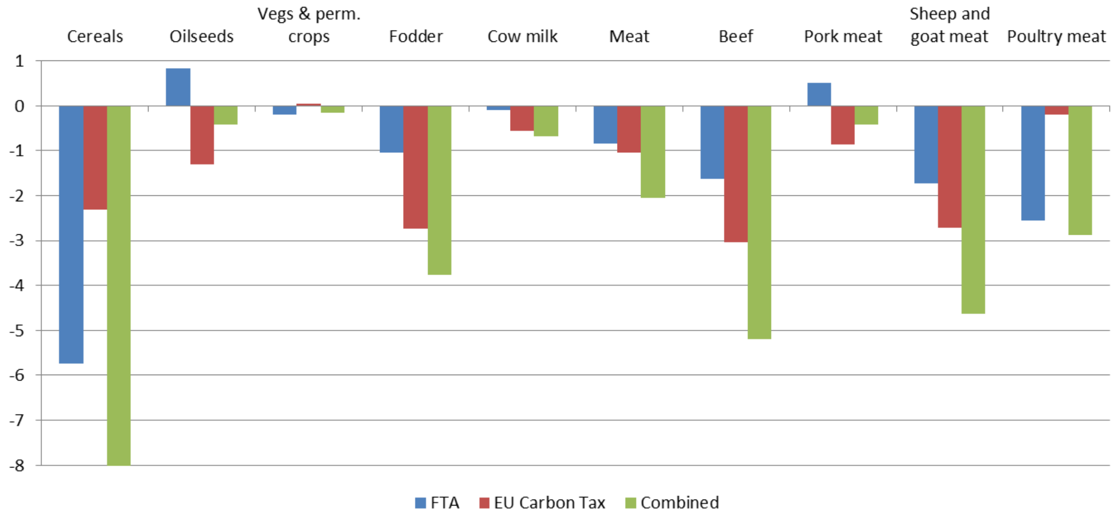
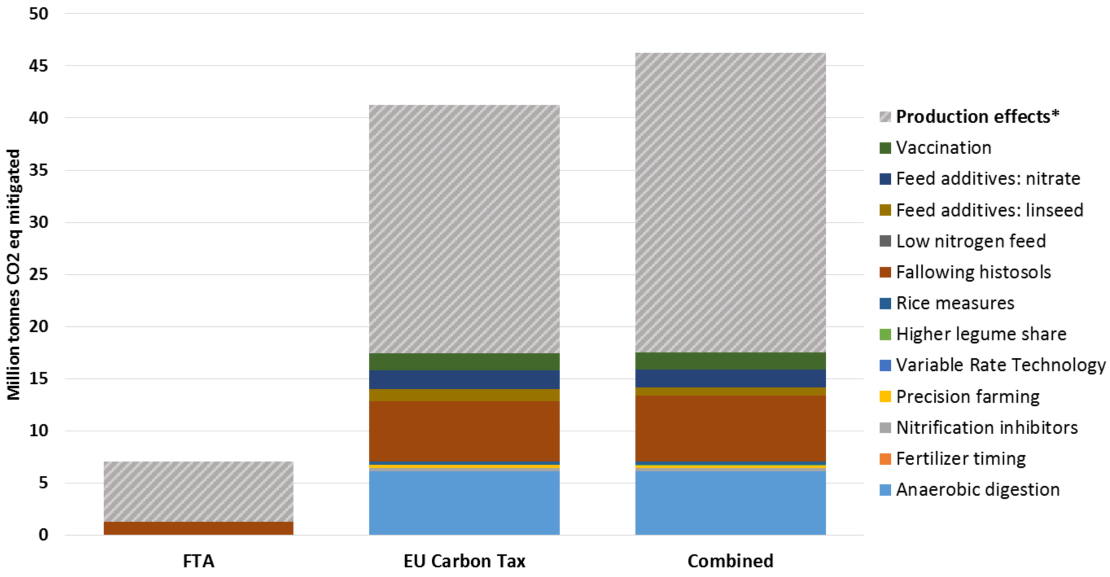


Figure 4.2 shows how each of the modelled technological GHG mitigation options contribute to the EU emission reduction in the three policy scenarios. The reference scenario is not indicated because the mitigation technologies are projected not to be widely implemented in the absence of a policy incentive, as in most cases adoption is not profitable for the farmers. This holds also in the FTA scenario, where only the measure 'fallowing of histosols' (i.e. organic soils taken out of production) is applied beyond the reference scenario level and contributes with about 17% to the total EU emission reduction in the FTA scenario. The remaining 83% of the emission reduction is due to decreased production levels. However, the positive uptake of the fallowing of histosols measure is a mere side effect of the above mentioned general increase of set aside and fallow land. It is therefore triggered by the loss of competiveness in the crop sector in the FTA scenario, and not by decreasing marginal costs as a result of adopting the measure. The picture changes in the EU Carbon Tax scenario, where the technological mitigation options contribute to 42% of the total emission reduction. Introducing the carbon tax triggers an adjustment in the marginal cost of production of agricultural activities, linking those to the emissions. Mitigation technologies improve emission efficiency and therefore reduce marginal costs in the presence of a carbon tax. In this case the marginal cost of adopting a measure is lower than the expected reduction in marginal cost, farmers' adopt the measure. Among the available voluntary measures, anaerobic digestion and fallowing of histosols are the technologies that contribute most to the total mitigation in the EU Carbon Tax scenario (about 15% and 14%, respectively), followed by nitrogen as feed additive (4.4%), vaccination against methanogenic bacteria in the rumen (4%) and linseed as feed additive (2.7%). In the Combined scenario, technological mitigation options contribute to 38% of the total EU emission reduction. The share is lower than in the EU Carbon Tax scenario, but this is due to the higher total reduction in the Combined scenario, i.e. the absolute contribution per mitigation technology is quite similar in both scenarios, with the biggest changes compared to the EU Carbon Tax scenario being a

further increase of almost 0.6 million tons CO_2 equivalents mitigated by the fallowing of histosols and 0.4 tons less by the use of linseed as feed additive.

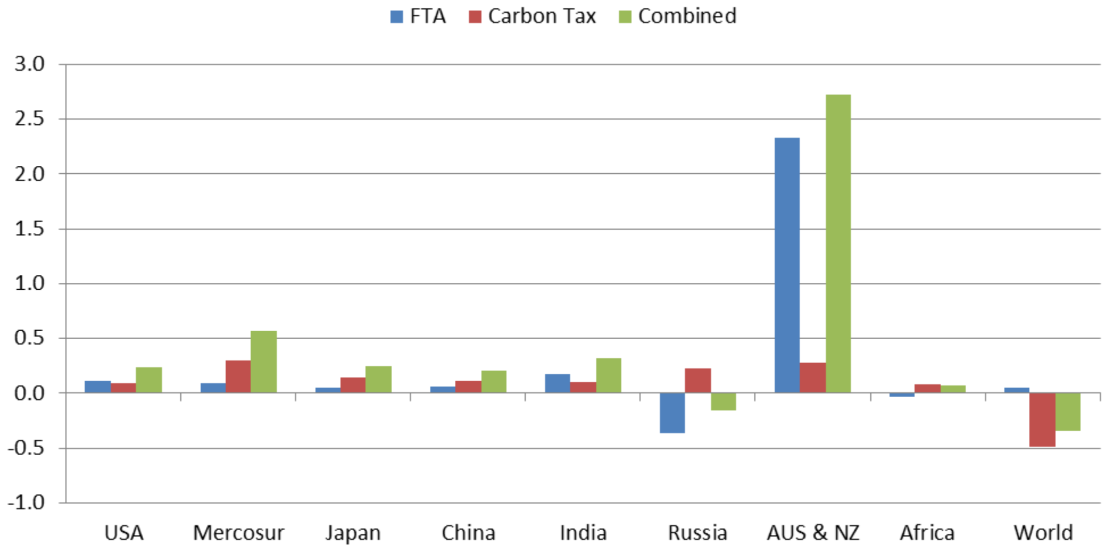
Figure 4.2: Contribution of the technological mitigation options to total EU emission reduction by 2030



* The mitigation effects linked to genetic improvement measures cannot be analyzed in isolation and are included in the mitigation achieved by changes in production.

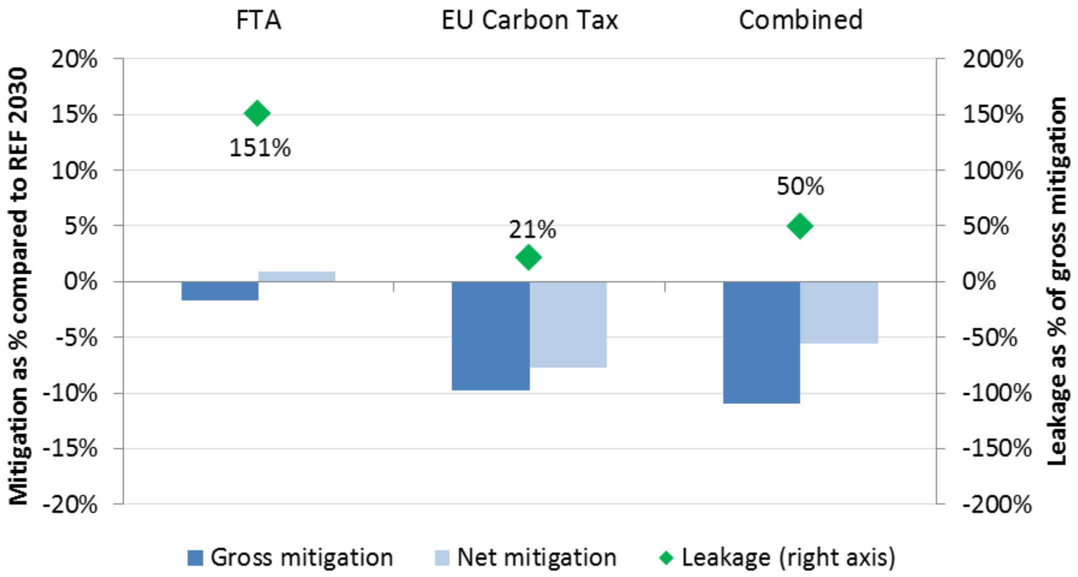
When investigating the interplay of trade and climate policies it is of major importance to assess net emission changes globally. The unilateral trade and climate reduction commitments of the EU in the simulated scenarios could in theory lead to positive or negative changes in global agricultural emissions, because production is shifted to more cost-efficient regions but these regions might be less efficient from a GHG emission perspective. Figure 4.3 shows that emission leakage indeed happens in our scenarios, as many non-EU countries increase their agricultural production to compensate for supply changes in the EU. The biggest increase in emissions is shown for Australia and New Zealand, where especially the cattle and sheep herds are increasing significantly in the EU Carbon Tax and Combined scenarios.

Figure 4.3: Global change in agricultural non-CO_2 emissions (%-change compared to reference scenario)



As shown in Figure 4.4, emission leakage is quite substantial in all three scenarios. In relative terms, emission leakage is highest in the FTA scenario, where the increase of emissions in the rest of the world more than offsets the reduction in the EU, leading to a situation where the FTA actually results in a net increase in total global emissions of almost 3.6 million tons CO_2 equivalents (which translates into a net increase in global agricultural emissions of about 0.1%). Emission leakage is relatively less in the EU Carbon Tax scenario, where 21% of the EU mitigation effort is leaked to non-EU countries, resulting in a net decrease in global agricultural emissions of 0.5%. Finally, emission leakage is again relatively higher in the Combined scenario (50%), resulting in a net decrease in total global agricultural emissions of 0.3%.

Figure 4.4: EU emission mitigation and leakage as percentage of gross mitigation



Most of the relatively lower emission leakage in the EU Carbon Tax scenario can be attributed to the above mentioned higher share of mitigation technologies (42%) in EU emission mitigation. A higher rate of adoption of mitigation technologies improves the carbon efficiency of EU agricultural production, and therefore decreases the negative supply effect of the carbon tax. In parallel, EU import demand becomes relatively smaller, which decreases the leakage effect, under the assumption that the EU's trading partners are less emission efficient. Accordingly, as the share of mitigation technologies in EU mitigation is lower in the Combined (38%) and especially the FTA (17%) scenario, emission leakage is relatively higher in these two scenarios. As mentioned above, the rate of technology adoption in the EU Carbon Tax and Combined scenarios is triggered by the carbon tax, as for the adopting farmers the marginal cost of applying the technologies is lower than the marginal cost of paying the tax or reducing production levels. The absolute level of the contribution of the mitigation technologies is basically the same in the two scenarios with the carbon tax in place, i.e. the FTA in the Combined scenario does not trigger more technology adoption in the EU. Instead, the FTA results in a drop of EU producer prices, leading to additional EU production decreases which are substituted by more competitive imports from third countries, but as these countries have higher emission factors (i.e. higher emissions per kg produced), the net effect in EU emission mitigation is further diminished by emission leakage. In the scenario without trade liberalization, in addition to the effect of technology uptake, tariffs allow EU agriculture to continue being more competitive due to higher domestic prices.

With respect to the sectoral economic welfare effects (i.e. only considering economic welfare linked to agricultural outputs, and not to other sectors or environmental externalities), our scenarios show that trade liberalization and the introduction of a carbon tax drive the results to different directions: the former puts a downward price pressure on EU agriculture, whereas the latter leads to the opposite effect and EU agricultural prices increase. The trade liberalization agenda of the EU leads to increasing consumer surplus in the FTA scenario (+12.3 billion Euros), as further opening up to international competition decreases EU food prices (Table 4.2). The impact on agricultural income in the EU is negative (-9.6 billion Euros) due to shrinking agricultural supply and lower producer prices. Conversely, the introduction of the carbon tax on non-CO_2 emissions generates a decrease in consumer surplus of about 5.4 billion Euros due to food price increases. The corresponding increase in producer prices would lead to increasing agricultural income in terms of gross value added before taxes (+6 billion Euros). In the Combined scenario, the downward price pressure of the trade liberalization dominates, resulting mostly in decreasing agri-food prices and consequently in larger consumer surplus, with a parallel (albeit lower) decrease in agricultural income.

Following a supply side implementation of the carbon tax, we account for the carbon tax directly under EU agricultural income. Assuming that farmers had to pay the full burden of the newly introduced carbon tax, EU agricultural income would decrease significantly in both scenarios involving a carbon tax, with a higher decrease in the Combined scenario (-13.6 billion Euros in the EU Carbon Tax scenario and -23.9 billion Euros in the Combined scenario). Avoiding the estimation of transaction costs related to monitoring agricultural emissions and collecting the tax from farmers, the carbon tax is added as a lump sum transfer to government revenues. Our partial equilibrium framework is not suitable for modelling possible options for redistributing that tax revenue back to economic agents. At least part of the tax revenue, however, could eventually be redistributed to farmers, e.g. by supporting the adoption of mitigation technologies, in order to further incentivize emission-efficient farming practices.

The profit of the processing industry is mostly affected by primary agricultural commodity prices: it either benefits from lower prices in the FTA scenario or is worse off due to increasing prices in the other scenarios. Tariff revenues increase in all scenarios mainly due to increased volumes of trade, taking into account that tariff cuts for sensitive products (whose trade contributes the most to total tariff revenues) are only partial. Tax payer costs of agricultural subsidies, that cover the costs of the Common Agricultural Policy, do not change significantly in any of the scenarios, which is partly due to the limited impacts on total agricultural supply in the EU, but also indicates that a significant part of the subsidies are decoupled from production.

Table 4.2: Decomposition of welfare effects in the EU agricultural sector, 2030

		FTA	**EU Carbon Tax**	**Combined**
		Absolute (Billion EUR) and percentage difference to the reference scenario		
a.	Consumer surplus	12.3 (0.06%)	-5.4 (-0.03%)	7.8 (0.04%)
b.	Agricultural income	-9.6 (-4.53%)	-13.6 (-6.44%)	-23.9 (-11.26%
	- excluding Carbon tax	-9.6 (-4.53%)	6.0 (2.82%)	-4.6 (-2.15%)
c.	Profit of processing industry	0.7 (1.75%)	-1.5 (-3.85%)	-0.8 (-2.03%)
d.	Tariff revenues and TRQ rents	0.8 (12.9%)	0.3 (4.04%)	1.3 (19.93%)
e.	Tax payers' cost of agricultural subsidies	-0.1 (-0.13%)	-0.1 (-0.14%)	-0.2 (-0.34%)
f.	Government revenue from Carbon tax	n.a.	19.6 (n.a.)	19.3 (n.a.)
	Total welfare change (a + b + c + d – e + f)[1]	4.3 (0.02%)	-0.7 (0%)	3.8 (0.02%)

[1] Total welfare effects linked to the EU agricultural sector, calculated as the sum of consumer surplus plus producer surplus (agricultural income and profits from the processing industry) plus tariff revenues minus taxpayer costs plus government revenue Carbon tax.

4.5 Sensitivity analysis

Tariff reduction in the FTA and Combined scenarios have been implemented in a simplified manner, using a full tariff elimination assumption on non-sensitive goods and a 50% tariff cut on sensitive ones. There is, however, a large uncertainty around the magnitude of the tariff cuts. For FTAs still under negotiation the final tariff schedules might lead to a less or more ambitious trade opening for the EU than those implemented in our scenarios. Similarly, the magnitude of a potential EU-wide carbon tax for agriculture is uncertain, as such a tax is currently not considered in the EU political discussions. Acknowledging the potentially significant impacts that the above uncertainties can have on simulated results, we provide a sensitivity analysis on the Combined scenario with alternative assumptions on trade liberalization and on the level of the carbon tax. By combining more and less ambitious trade liberalization assumptions with a higher and lower rate for the carbon tax, a total of four alternative scenarios are compared to the Combined scenario described in the previous sections (Table 4.3).

Table 4.3: Combined scenario assumptions for the sensitivity analysis

	Trade liberalization	
	Less ambitious	**More ambitious**
Lower carbon tax	**LA_LT scenario** 25% tariff cut on sensitive products, 50% tariff cut on non-sensitive products, 25 EUR/t CO2 eq. carbon tax	**MA_LT scenario** 75% tariff cut on sensitive products, 100% tariff cut on non-sensitive products, 25 EUR/t CO2 eq. carbon tax:
Higher carbon tax	**LA_HT scenario** 25% tariff cut on sensitive products, 50% cut on non-sensitive goods, 100 EUR/t CO2 eq. carbon tax	**MA_HT scenario** 75% tariff cut on sensitive products, 100% tariff cut on non-sensitive goods, 100 EUR/t CO2 eq. carbon tax

The results of the sensitivity analysis confirm the main drivers of EU emission changes. The reduction in EU non-CO_2 emissions is driven mainly by the introduction of a carbon tax on agriculture. Correspondingly, none of the lower carbon tax scenarios reaches a comparable level in emission savings to the Combined scenario. Even in the case of a more ambitious trade agenda, emission savings in EU agriculture hardly reach 25 million tonnes of CO_2 equivalents. In contrast, doubling the carbon tax relative to the Combined scenario increases emission savings by more than 50%. Combining the higher carbon tax with a more ambitious trade agenda provides relatively small additional benefits in terms of emission savings, with only about 6 million tonnes of CO_2 equivalents difference between MA_HT and LA_HT. The application of some technological mitigation options increases with an increasing carbon tax, but the larger part of the emission savings is attributed to the production effect (Annex Figure A 4.1).

In the Combined scenario we observed that both trade liberalization and the introduction of a carbon tax contribute to increasing non-CO_2 agricultural emissions in non-EU countries, due to a relatively emission-efficient EU agriculture and to shrinking EU agricultural supply. These tendencies are confirmed by the sensitivity analysis. A more ambitious liberalization combined with a higher carbon tax (MA_HT) increases emissions in third countries the most, with the FTAs being responsible for the lion share of the impacts (Annex Figure A 4.2). Accordingly, the driving forces for emission leakage are also confirmed by the sensitivity analysis (Annex Figure A 4.3 and Figure A 4.1). A more ambitious trade agenda would increase emission leakage at all levels of an EU carbon tax, and the lower carbon tax is not sufficient to offset the induced emission leakage to non-EU countries, with an emission leakage coefficient similar to the pure FTA scenario (123% in MA_LT vs. 151% in FTA). On the other hand, a higher carbon tax reduces EU emissions to such an extent that emission leakage under more ambitious trade liberalization only slightly increases (from 50% in Combined to 65% in MA_HT).

4.6 Discussion and conclusions

Our findings provide some empirical evidence on a negative (and significant) effect of trade liberalization on GHG mitigation efforts in EU agriculture. The Combined scenario shows that the current EU trade liberalization agenda would undermine the global mitigation that could be achieved with unilateral measures in the EU[25]. Would the EU accomplish its trade liberalization agenda while

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[25] Although we implement a specific carbon tax on agricultural non-CO_2 emissions, the carbon tax can also mimic the operation of a larger policy package including possible elements of efforts for improved emission efficiency (e.g., farmers' education, cost compensation for the adoption of technological GHG mitigation

setting a sector specific mitigation policy for the agricultural sector this could more than double emission leakage rates (Figure 4.4). However, the combined impact of the simulated trade liberalization and EU carbon tax would still result in net mitigation of global agricultural non-CO_2 emissions (Figure 4.3). Contributing to the stream of literature examining the empirical measurement of the trade-liberalization – GHG emissions nexus, we conclude that trade liberalization in the agricultural sector by the EU does not lead to environmental gains. Regarding the interplay of trade and climate policy, we find that the negative impact on non-CO_2 GHG emissions of trade liberalization is smaller than the positive emission impact of climate policy. However, the relative impact varies by region and commodity, which potentially allows designing a more targeted approach to avoid the contradicting impacts of both policies.

With respect to unilateral mitigation efforts, our results on emission leakage are in line with the majority of empirical evidence in the literature (e.g. Lee et al. 2007; Herrero et al. 2016; and previous work with CAPRI in Pérez Dominguez et al. 2012, 2016; Van Doorslaer et al. 2015; Fellmann et al. 2017), although some authors find that unilateral emission reduction policies can lead primarily to a loss in competitiveness rather than to significant emission leakage effects (Matoo and Subramanian 2013).

Regarding the trade-liberalization – GHG emissions nexus, our simulated trade-liberalization impacts on global mitigation efforts of agricultural non-CO_2 emissions are negative. The negative net effect of the modelled FTAs on global agricultural GHG emissions is due to an increase in production in non-EU countries with relatively high emission intensities (more GHG emissions per kg produced). In the scenarios with a successful EU FTA agenda in place, production increases are, for example, especially shown for Australia and New Zealand with respect to beef and sheep meat as well as dairy production. Both countries have generally more extensive production systems than the ones in the EU, which are on the one hand very competitive on the international markets, but, on the other hand, come along with higher emissions per kg produced. Therefore Australia and New Zealand substantially contribute to the simulated emission leakage effects, with more than 5.4 and 6.3 million tons CO_2 eq. in the FTA and the Combined scenario, respectively, compared to 0.6 million tons of CO_2 eq. in the EU Carbon Tax scenario without a FTA in place. It has to be mentioned that our modelling approach is not able to decompose the total environmental impacts to scale, composition and technique effect. The modelling approach for non-EU emissions does not capture technology transfer or additional efforts in non-EU countries to increase emission efficiency. We rather focus on the scale and composition effects, as the Armington approach to trade covers the change in import demand patterns, and the partial equilibrium framework of CAPRI takes into account the supply side adjustments in agriculture and primary processing in great detail.

As outlined in the literature, the extent of emission leakage and hence the net gain of national mitigation efforts for global GHG emission reduction depends significantly on the relative GHG efficiency (i.e. emissions per unit of output) of agriculture in the exporting countries compared to the importing country (Caro et al. 2014; Pérez Domínguez and Fellmann 2015; Scott and Barrett 2015). Additional measures to assure that compensatory actions are taken for the specific product/origin combination most affected by trade liberalization would assure the integrity of the

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measures) and even compulsory GHG mitigation measures (e.g. reduction targets). Thus the generalization of our results to a broader set of policies is to some extent possible, however, the welfare implications would vary depending on the policy instrument implemented.

climate change mitigation efforts of the EU. Although we do not go into a political economy discussion on the viability of the above policy options, our finding may support combining a unilateral EU carbon tax with other policy instruments (such as border tax adjustments) in order to prevent or reduce the leakage effect. However, border tax adjustments, such as tariffs on imports based on the emission intensity of their production could be in conflict with many objectives of the EU trade agenda. Moreover, border adjustment measures are often seen as an inappropriate and non-useful measure, especially in the context of WTO rules and due to potentially negative welfare effects in particular for developing countries (Frankel 2008; Stavins et al. 2014).

In our analysis we do not calculate with possible regional FTAs outside the EU's trade agenda, or with a successful completion of the current WTO negotiation round. Therefore the gains from trade for the EU and for its FTA partners are probably overestimated. The impact of this assumption on simulated emission leakage effects is ambiguous, as the EU may manage to expand production (and related emissions) for commodities where it traditionally has an export position in global markets (e.g. dairy) while the opposite holds for commodities where imports may grow significantly (e.g. beef). In this context it has to be mentioned that in our analysis emissions from the transport sector are also not taken into account, which is a rapidly growing source of emissions itself with obvious linkages to increased international trade in goods. We concentrate on non-CO_2 emissions (where agriculture is an important emitter) and we do not take into account CO_2 emissions (or sinks) from the land use, land-use changes and forestry (LULUCF) sector.

It has to be highlighted that the reported emission leakage impacts crucially depend on the estimated emission coefficients for the commodities produced in non-EU countries. As EU agriculture is assumed to be relatively emission efficient globally, the substitution of domestic EU production with less emission efficient imports offsets the emission savings in the EU, leading to emission leakage that can eventually result in a net increase in global emissions. While our approach for estimating emission factors for non-EU countries takes into account the changes in emission intensities over time (based on past trends), technological mitigation options are not specifically considered in the model outside the EU. Thus, changes in emission factors outside the EU are not model-endogenous (but rather fixed) in our comparative simulations. As our scenarios with the EU Carbon Tax show, the application of mitigation technologies contributes to the reduction of EU emissions from agriculture and at the same time moderates the negative supply effect on EU production, hence diminishing emission leakage effects. The lack of model-endogenous mitigation technologies in non-EU countries limits the validity of the simulated effects on emission leakage, but whether the leakage effects are over- or underestimated depends on the particular mix of emission intensity changes globally. It remains for further research to calculate emission factors for commodities produced in non-EU countries under different technological development options.

Furthermore, we assume a unilateral climate action from the EU, which distorts relative carbon prices extremely in favor of non-EU countries. The resulting lower competitiveness of the EU agricultural sector on global markets probably adds to an overestimated impact on trade in our Combined scenario. Accordingly, the extent of emission leakage depends on the commitments other countries make regarding their contributions to the Paris Agreement. It remains to be seen how the global climate agreement will be put into action, but our scenario results show that multilateral commitments will be necessary not only in the light of emission leakage and global emission mitigation but also with respect to minimizing distortions to agricultural competitiveness arising from unilateral emission mitigation obligations.

Notwithstanding the above caveats, our paper provides an unambiguous message, as it points to the importance of the cross negotiation of free trade agreements together with the design of National Determined Contributions (NDCs) within the Paris Agreement, assuring that mitigation efforts are not undermined in sectors where trade is forecasted to increase the most. Depending on the relative development of the trading partners, the mitigation efforts could be partly funded by the developed party of the free trade agreement, by both parties or by the emitting party.

4.7 References

AnimalChange (2015): An Integration of Mitigation and Adaptation Options for Sustainable Livestock Production under Climate Change, http://www.animalchange.eu/.

Armington, P.S. (1969): A theory of demand for products distinguished by place of production. IMF Staff Papers 16, 159-178.

Barreiro-Hurlé, J., Pérez-Dominguez, I., Jansson, T., Fellmann, T., Weiss, F. (2016): Can technology transfer avoid emission leakage from unilateral mitigation targets in agriculture? Contributed paper 2016 AAEA Annual Meeting, Boston 31 July – 2 August.

Boulanger, P., Dudu, H., Ferrari, E., Himics, M., M'Barek, R. (2016): Cumulative economic impact of future trade agreements on EU agriculture. JRC Science for Policy Report, European Commission, Luxembourg: Publications Office of the European Union. http://dx.doi.org/10.2788/194880.

Britz, W. and P. Witzke (2014): CAPRI model documentation 2014, http://www.capri-model.org/docs/capri_documentation.pdf.

Caro, D., LoPresti, A., Davis, SJ., Bastianoni, S., Caldeira, K. (2014): CH4 and N2O emissions embodied in international trade of meat. Environmental Research Letters 9, 114005.

Copeland B.R., Scott Taylor, M. (2004): Trade, Growth, and the Environment. Journal of Economic Literature, 42 (1): 7-71.

European Commission (2015) EU Agricultural Outlook - Prospects for EU agricultural markets and income 2015-2025, DG Agriculture and Rural Development. https://ec.europa.eu/agriculture/sites/agriculture/files/markets-and-prices/medium-term-outlook/2015/fullrep_en.pdf.

European Council (2009) Decision 406/2009/EC of the European Parliament and of the Council of 23 April 2009 on the effort of Member States to reduce their Greenhouse gas emissions to meet the Community's greenhouse gas emission reduction commitments up to 2020. Official Journal of the European Union, L140/63.

Fellmann, T., P. Witzke, F. Weiss, B. Van Doorslaer, D. Drabik, I. Huck, G. Salputra, T. Jansson, A. Leip (2017): Major challenges of integrating agriculture into climate change mitigation policy frameworks. Mitigation and Adaptation Strategies for Global Change. http://dx.doi.org/10.1007/s11027-017-9743-2.

Frankel, J. (2008): Global environmental policy and global trade policy. Discussion paper 08–14. Harvard John F. Kennedy School of Government, Cambridge, MA http://www.belfercenter.org/sites/default/files/legacy/files/Frankel2Web.pdf.

GAINS database (2013): Greenhouse Gas and Air Pollution Interactions and Synergies. International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria. http://www.iiasa.ac.at/web/home/research/researchPrograms/GAINS.en.html.

GAINS database (2015): Greenhouse Gas and Air Pollution Interactions and Synergies. EU-28: GAINS model input data and results. Internal document produced for the JRC by the International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria.

Gernaat, DEHJ, Calvin, K, Lucas, PL, Luderer, G., Otto, SAC, Rao, S., Strefler, J., van Vuuren, DP. (2015): Understanding the contribution of non-carbon dioxide gases in deep mitigation scenarios. Global Environmental Change 33, 142–153.

Grossman, G.M., Krueger, A.B. (1991): Environmental impacts of a North American Free Trade Agreement. National Bureau of Economic Research Working Paper 3914.

Herrero, M., B. Henderson, P. Havlík, P.K. Thornton, R.T. Conant, P. Smith, S. Wirsenius, A.N. Hristov, P. Gerber, M. Gill, K. Butterbach-Bahl, H. Valin, T. Garnett, E. Stehfest (2016): Greenhouse gas mitigation potentials in the livestock sector. Nature Climate Change 6, 452–461.

Himics, M., Artavia, M., Hélaine, S., Boysen, O. (2014): Calibrating the CAPRI and ESIM models to the mid-term commodity market outlook of the European Commission. JRC Technical Reports, European Commission, Seville: Joint Research Centre.

Himics, M., Britz, W. (2016): Flexible and welfare-consistent tariff aggregation over exporter regions. Economic Modelling 53, 375–387. doi:10.1016/j.econmod.2015.10.024.

Höglund-Isaksson, L., W. Winiwarter, P. Purohit (2013): Non-CO2 greenhouse gas emissions, mitigation potentials and costs in the EU-28 from 2005 to 2050. GAINS model methodology. International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria.

Höglund-Isaksson, L., W. Winiwarter, P. Purohit, A. Gomez-Sanabria (2016): Non-CO2 greenhouse gas emissions in the EU-28 from 2005 to 2050: Final GAINS Reference scenario 2016. GAINS model methodology. IIASA Report, International Institute for Applied Systems Analysis, Laxenburg, Austria.

Huang, H., M. von Lampe, F. van Tongeren (2011): Climate change and trade in agriculture. Food Policy 36, S9-S13.

IPCC (2006): 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Prepared by the National Greenhouse Gas Inventories Programme. Eggleston HAS., Biennia L., Miwa K., Negara T. and Tanabe K. (eds). Published: IGES, Japan.

Jansson, T., Perez Domínguez, I., Weiss, F. (2010): Estimation of Greenhouse Gas coefficients per commodity and world region to capture emission leakage in European Agriculture. Paper presented at the 119th EAAE seminar “Sustainability in the Food Sector”, Capri, Italy.

Jansson, T. Pérez Domínguez I. (2014): Greenhouse gas emission coefficients per commodity estimated globally using Aglink-Cosimo and FAOSTAT data and IPCC methods, OECD internal document.

Lee, H.C., B.A. McCarl, U.A. Schneider, C.C. Chen (2007): Leakage and Comparative Advantage Implications of Agricultural Participation in Greenhouse Gas Emission Mitigation. Mitigation and Adaptation Strategies for Global Change 12(4), 471–494.

Leip, A., F. Weiss, T. Wassenaar, I. Perez, T. Fellmann, P. Loudjani, F. Tubiello, D. Grandgirard, S. Monni, K. Biala (2010): Evaluation of the livestock sector’s contribution to the EU greenhouse gas emissions (GGELS). European Commission, Joint Research Centre, Brussels, http://ec.europa.eu/agriculture/analysis/external/livestock-gas/index_en.htm.

Mattoo, A., A. Subramanian (2013): Greenprint: A New Approach to Cooperation on Climate Change. Center For Global Development, Washington D.C.

OECD-FAO (2015): OECD-FAO agricultural outlook 2015-2024. Organisation for Economic Cooperation and Development, Paris, and Food and Agricultural Organisation of the United Nations, Rome, OECD Publishing and FAO.

Pérez Domínguez, I. (2006): Greenhouse Gases: Inventories, Abatement Costs and Markets for Emission Permits in European Agriculture - A Modelling Approach, Peter Lang, Frankfurt a.M.

Pérez Domínguez, I., T. Fellmann (2015): The need for comprehensive climate change mitigation policies in European agriculture. Euro Choices 14(1), 11–16.

Pérez Domínguez, I., T. Fellmann, F. Weiss, P. Witzke, J. Barreiro-Hurle, M. Himics, T. Jansson, G. Salputra, A. Leip (2016): An economic assessment of GHG mitigation policy options for EU agriculture (EcAMPA 2). JRC Science for Policy Report, European Commission, Luxembourg: Publications Office of the European Union. http://doi.org/10.2791/843461.

Pérez Domínguez, I., T. Fellmann, H.P. Witzke, T. Jansson, D. Oudendag, A. Gocht, D. Verhoog (2012): Agricultural GHG emissions in the EU: An Exploratory Economic Assessment of Mitigation Policy Options. JRC Scientific and Policy Reports, European Commission, Seville, http://doi.org/10.2791/8124.

Peters, G.P., E.G. Hertwich (2008): CO2 embodied in international trade with implications for global climate policy. Environmental Science & Technology 42(5), 1401–1407.

Peters, G.P., J.C. Minx, C.L. Weber, O. Edenhofer (2011): Growth in emission transfers via international trade from 1990 to 2008. Proceedings of the National Academy of Sciences of the United States of America 108 (21), 8903–8908.

Philippidis, G., Resano-Ezcaray, H., Sanjuán-López, A.I. (2013): Capturing zero-trade values in gravity equations of trade: an analysis of protectionism in agro-food sectors. Agricultural Economics 44, 141–159. https://doi.org/10.1111/agec.12000

Philippidis, G., Resano, H., Sanjuán, A.I. (2014): Shifting Armington trade preferences: A re-examination of the Mercosur–EU negotiations. Economic Modelling 40, 21–32. https://doi.org/10.1016/j.econmod.2014.03.016

Stavins R., et al. (2014): International Cooperation: agreements and instruments. In: Edenhofer et al (eds) Climate change 2014: mitigation of climate change. Contribution of working group III to the fifth assessment report of the IPCC. Cambridge University Press, Cambridge

Scott, K., Barrett, J. (2015): An integration of net imported emissions into climate change targets. Environmental Science & Policy 52, 150–157.

Van Doorslaer, B, P. Witzke, I. Huck, F. Weiss, T. Fellmann, G. Salputra, T. Jansson, D. Drabik, A. Leip (2015): An economic assessment of GHG mitigation policy options for EU agriculture (EcAMPA). JRC Technical Reports, European Commission, Luxembourg: Publications Office of the European Union. http://dx.doi.org/10.2791/180800.

Wiedmann, T., Lenzen, M., Turner, K., Barrett, J. (2007): Examining the global environmental impact of regional consumption activities - Part 2: Review of input-output models for the assessment of environmental impacts embodied in trade. Ecological Economics 61, 15–26.

Wollenberg E, et al (2016): Reducing emissions from agriculture to meet the 2 °C target. Global Change Biology 22, 3859–3864.

4.8 Appendix

Figure A 4.1: Contribution of the technological mitigation options to total EU emission reduction by 2030, sensitivity analysis results

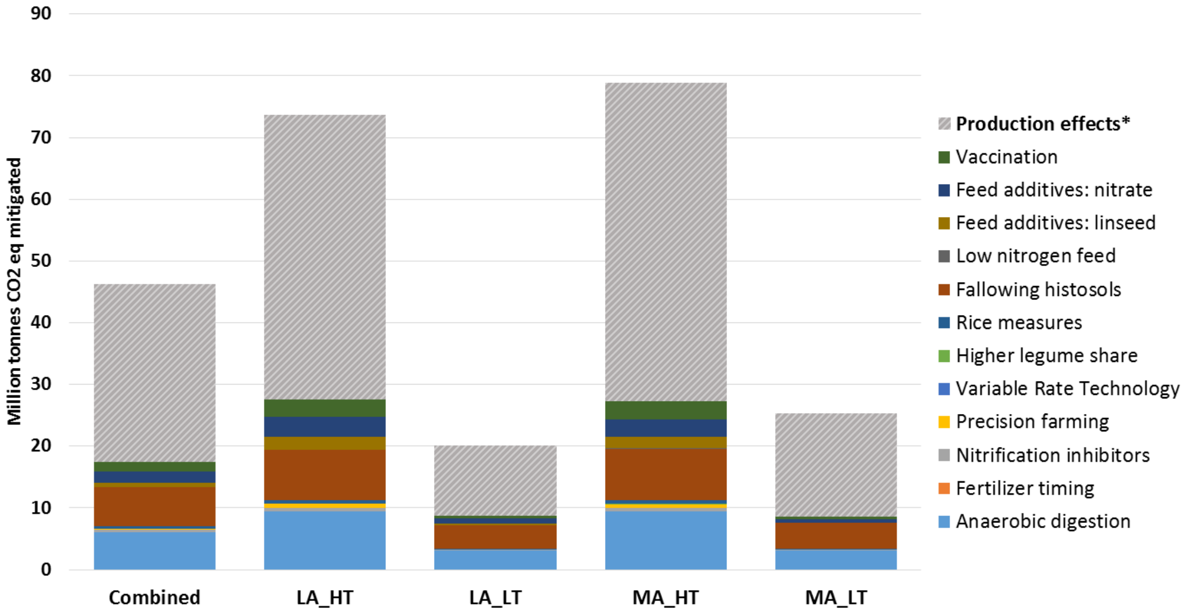

Figure A 4.2: Global change in agricultural non-CO_2 emissions, sensitivity analysis results (%-change compared to reference scenario)

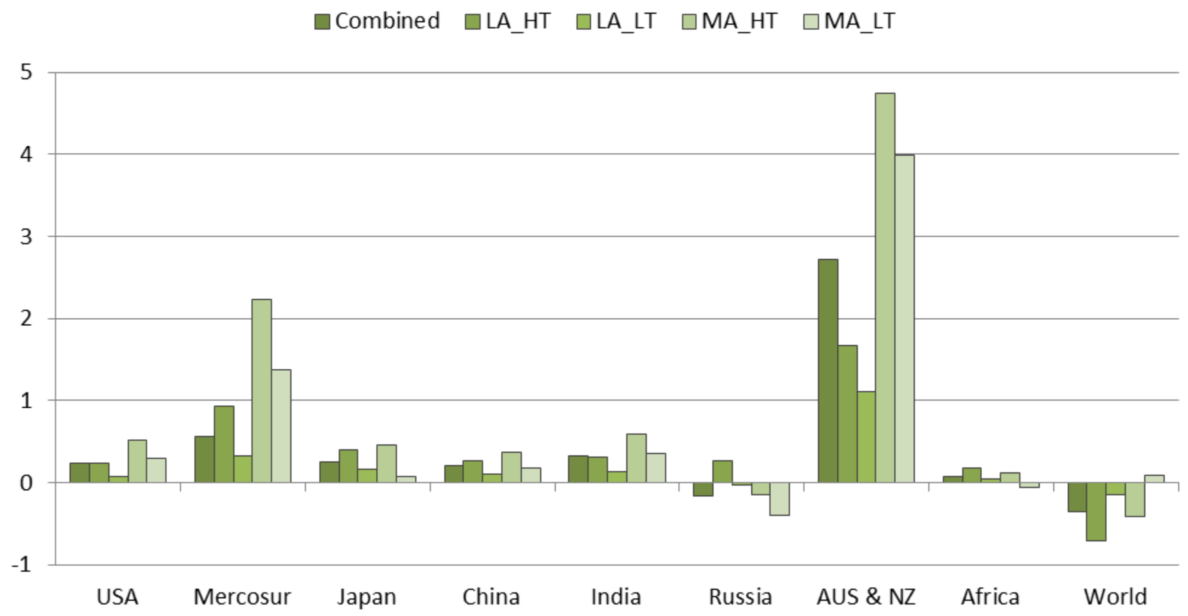

Figure A 4.3: EU emission mitigation and leakage as percentage of gross mitigation, sensitivity analysis results

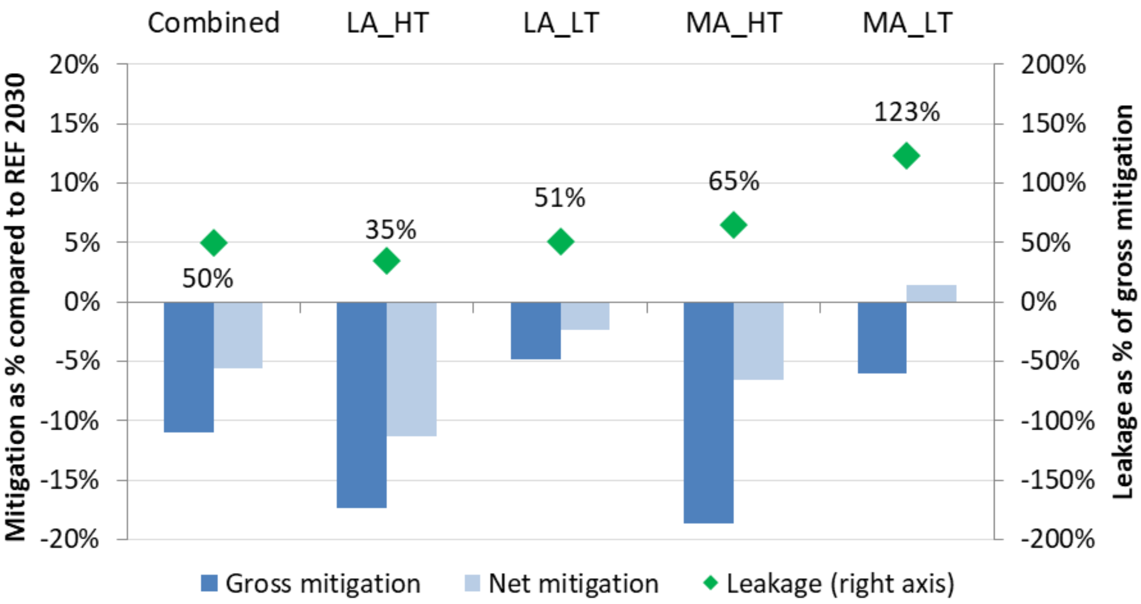

Figure A 4.4: Percentage change in EU agricultural supply compared to the reference scenario (2030), sensitivity analysis results