BATModel

better agri-food trade modelling for policy analysis

Deliverable 2.2
Detailed trade model

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Dissemination Level

P	Public	X
CO	Confidential, only for members of the consortium (including the Commission Services)	
CI	Classified, as referred to Commission Decision 2001/844/EC	

Type

R	Document, Report	X
DEM	Demonstrator, Pilot, Prototype	
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EXECUTIVE SUMMARY

This report provides detail about the methodological advancements established for improved trade flow modelling at disaggregated level such as HS6. Two approaches are presented and combined. The first one solely splits selected bilateral trade flows by tariff line, while the other disaggregates the GTAP Data Base to more agro-food detail. These methods reduce aggregation biases, especially by depicting substitution effects and the impact of tariff liberalisation more accurately.

Increased detail renders the emergence and disappearance of trade flows more likely, which cannot be modelled based on the commonly applied CET and CES functions. This issue is addressed by defining trade shares of selected products based on a Spatial Price Equilibrium Model. While the standard Armington approach differentiates quality by origin, the Spatial Price Equilibrium Model assumes homogeneous quality for selected products and thus the law of one price. In an example case, all three methods are applied together using the CETA agreement as trade shock.

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INTRODUCTION

In the context of trade modelling, a disaggregated trade flow database is essential. In particular, agricultural and food products are subject to the highest rates of protection globally making an appropriate accounting decisive. Since trade policy is often set on the basis of very detailed product definitions, there is considerable dispersions of tariffs across products within aggregated product groups. Thus, for (potential) Free Trade Agreement assessments, detail beyond the sectors of commonly applied data such as the GTAP Data Base (Aguilar et al., 2019) is required. Properly depicting substitution between products for example as a result of a trade shock also builds on higher product detail. Product aggregation may suggest substitution possibilities and consequently competition in demand which does not arise or only to a limited degree at the more detailed product level.

As a result, specialized (Partial Equilibrium) modelling systems for agro-food markets or land-use offer large product detail at regional level. Given their global focus and suitability for trade analysis, advancements are also made with databases applied in Computable General Equilibrium (CGE) models. In the following, two methods are described, being the extended GTAP Data Base called GTAP-AGROFOOD (Britz, 2022) and a Tariff Line module developed in an application for CGEBox (Jafari et al., 2021; 2022). Both methods are compared to the disaggregated GTAP-HS model (Chepeliev et al., 2021) which also incorporates tariff line detail to the GTAP Data Base following a different approach.

Implementing such highly detailed databases highlights known issues with functional forms that are commonly applied in CGE models to represent trade decisions. The standard CES/CET trade representation uses the Armington assumption, does not capture zero observations of trade, and suffers from the “small shares stay small” problem. Thus, in a more disaggregated database, with more trade shares being small or even zero, these problems become more prominent.

The Armington assumption implies that quality differences arise depending on the region of origin. In many cases, this assumption is reasonable since each aggregated product in the GTAP Data Base consists of many different tariff lines and differs in the composition across regions. However, with the disaggregated database including for example commodities such as sugar or single grains the assumption of a homogenous quality and the law of one price might be more appropriate. These assumptions can be employed at the level of bilateral flows with the spatial arbitrage solution drawing on the Spatial Price Equilibrium framework. It allows for emerging and disappearing trade flows and does not require any behavioural parameters to steer substitution between the different origins, as needed for alternative functional forms.

In the following, the report presents the GTAP-AGROFOOD database, the Tariff Line module and details the methodological approach applied to build a Spatial Price Equilibrium model into CGEBox. Furthermore, it demonstrates an example case that implements the three methodologies together for an analysis of the tariff changes induced by the CETA Agreement.

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OBJECTIVES

The aim of the exercise documented here, as outlined in the introduction, is to:

- describe options to disaggregate trade flows, through modelling at the tariff line and disaggregation of the global GTAP database to higher agri-food detail.
- describe the methodology developed to implement an SPE model which replaces the Armington assumption for selected products to treat them as perfect substitutes.
- demonstrate the differences in results that arise through the application of combinations of the discussed methods when analysing bilateral trade liberalisation as part of the CETA Agreement.

METHODS

Different ways can be pursued to implement a disaggregation of trade flows in CGE models. Either the model can be linked to a partial equilibrium model which incorporates tariff line detail or all parts of the model can itself be extended to depict more detail. A disaggregation of the full model to tariff line detail is numerically challenging (Himics & Britz, 2016) and key data such as on supply or demand at this level are not generally available. One alternative is to provide pre-model aggregation of the shocks such as various ways to aggregate tariff change from tariff line to product level (see Jafari et al., 2021). Here, the reference group method is often used (Guimbard et al., 2012) which applies trade data from a block of reference as weights, to avoid the endogeneity bias that occurs when relying on observed bilateral trade as aggregation weights instead. However, such pre-model aggregation neglects substitution effects at the tariff line. The approaches discussed in the following therefore extend the model to reduce aggregation bias and provide more detailed results.

Tariff Line module

The Tariff Line module allows to disaggregate selected bilateral trade flows to a higher detail and to explicitly model Tariff Rate Quotas (TRQs) at the detailed level. It models selected bilateral trade links at the tariff line while maintaining otherwise the chosen default trade representation. The largest part of the model structure stays unchanged. If a solver for Mixed-Complementarity Problems (MCP) is available, multiple TRQs at bilateral tariff line can be introduced to render applied tariff rates endogenous. The Tariff Line module depicts substitution between commodities at the tariff line level which also implies an endogenous aggregation rather than relying on pre-model aggregation.

The chosen approach extends in our example the usual two-stage CES/CET approach to model bilateral trade in CGE and certain partial equilibrium models by a third tier at tariff line for selected trade links. The two-state CES/CET approach defines demand or supply and related price indices based on a (1) first level Armington nest between domestic sales and aggregate imports/exports, followed by a (2) second level Armington nest which steers the bilateral trade at commodity level. The Tariff Line module differentiates some of these bilateral trade flows further to tariff line level. Splitting products down to the tariff line at this third stage for some flows only considerably reduces data requirements and the computational burden. It requires merely information on tariffs and trade at the tariff line level for the selected bilateral links instead of for all. Thus, data on domestic sales at tariff lines, which tend to be unavailable, are

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also not needed in this methodology. Maintaining manageable model size is of particular relevance when modelling TRQs which is numerically more demanding.

The Tariff Line model is integrated into CGEBox. When the module is activated, the user has to supply observed trade and tariff data, as well as changes in tariffs applied in the counterfactual run, at the tariff line in separate files. Additionally, such files need to include the mapping of the tariff lines to the GTAP sectors contained in the database of the model run, as well as substitution and transformation elasticities. All bilateral trade links for which no information on trade at tariff line is provided remain automatically at the standard two-stage trade representation. Finally, when introducing TRQ, in- and out-of-quota rates must be defined. Based on this information, equations and variables for the selected trade links are added to the model structure. The collected data on trade and tariffs at the benchmark are fitted to the given aggregated data on bilateral trade and matching share parameters are defined.

This CGE extension requires first the additional CES/CET share equations for bilateral import/export demand/supply at the tariff line level. Dual price aggregators for bilateral export supply and import demand prices are defined, which provide the link to the rest of the model operated at aggregated commodity level. Further new equations replacing the ones at the aggregated level include: a market clearing condition equalising bilateral export supply and import demand at tariff line level, and price transmission equations linking domestic prices to bilateral import and export prices at the tariff line. The latter equation takes import tariffs, export subsidies and transport margins into account. All equations used for the implementation can be found in Jafari et al. (2021) and the CGEBox documentation (Britz, 2021a).

AGROFOOD Database

Instead of disaggregating solely some trade related part of the model, all dimensions in a CGE and PE model can be applied to more detailed databases, which also implies higher detail for bilateral trade. An example for this approach is the so-called AGROFOOD database which disaggregates the GTAP V10 Data Base to high level for agri-food products, in many cases down to the HS6 level (Britz, 2022). It maintains the full regional and factor detail of the original GTAP V10 Data Base, including the detail for not further disaggregated products and sectors. Higher level of detail with more than 40 additional agri-food products compared to GTAP V10 is achieved by using data from FABIO (for disaggregation of production, land use and intra-agro-food intermediate use, Bruckner et al., 2019), FAOSTAT (detail for dairy), and TASTE V10 (for data on bilateral trade and related tariff revenues, Pelikan et al., 2020). This disaggregation process is based on a linear loss framework from Britz (2021b).
The extended product and sector detail provided by the new database are listed in Britz (2022) linking the new sectors to the initial GTAP product groups. The level of additional detail differs across the 11 aggregated agro-food products in the GTAP Data Base. FABIO and TASTE would allow even higher detail which could be used to derive alternative databases. AGROFOOD provides a compromise, not at least to avoid issues with numerical instability of the data processing chain, by aggregating parts of the FABIO database based on agronomic knowledge of product similarities.

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The split procedure used to derive the AGROFOOD database is integrated in the database driver of CGEBox (Britz and van der Mensbrugghe, 2018). Departing from the full GTAP V10 Data Base, small cost, use and trade shares are first removed in order to reduce numerical problems. Corrections, such as elimination of non-diagonal crop uses, downscaling seed costs to less than 50% of total production value per crop and minimising any cost share of each production activity to 10% of the value added in total production costs are subsequently applied. In parallel, further corrections are introduced, such as deleting any tax rates below 1E-6. Uniform emission factors for CO_2, non-CO_2 and air pollution emissions across disaggregated products and activities deliver estimated detailed emission inventories. Shares on factor demand of land at country level are used to split-up the AEZ database to the additional crop and animal sectors. More detail on the methodology can be found in Britz (2022).

The AGROFOOD database can be combined with the Tariff Line module describe above, adding even more detail to the trade flow representation.

Comparison of method providing additional trade detail in CGE modelling

As outlined above different ways of addressing aggregation biases exist. An intermediate option to the two afore-mentioned methodologies is the so-called GTAP-HS model, applied by Chepeliev et al. (2021) to provide additional detail for some agricultural products. They use FAO statistical data to extend parts of the GTAP Standard model structure to the tariff line level. In opposite to the Tariff Line module described above, a CET distributes the aggregated output of all model regions for the selected sectors to the tariff lines disaggregating output, domestic sales, exports and bilateral trade. This requires related data for these positions (Chepeliev et al., 2021). As such, this approach is more data intensive than the Tariff Line module, but requires less data than the development of the AGROFOOD database.
The differences between the three approaches in terms of detail and where detail is present in the model structure are depicted in Figure 1.

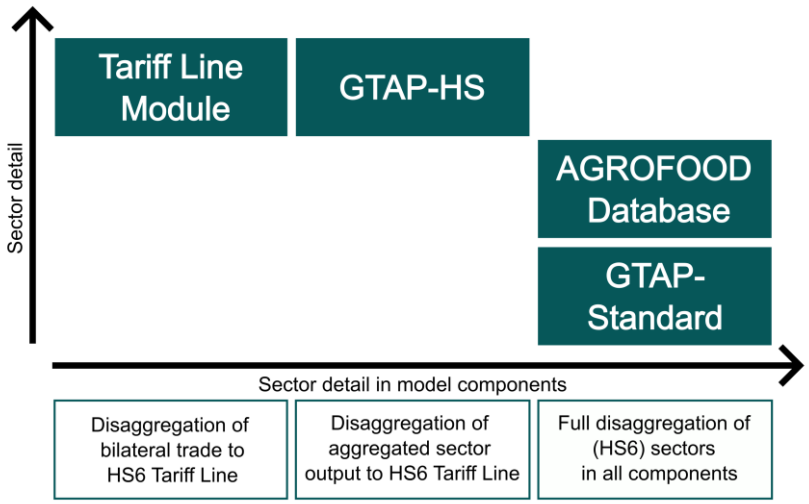

Figure 1. Level of detail regarding sector disaggregation for the three methods compared

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Spatial Price Equilibrium

At the product detail present in the model, in our case the additional agri-food detail available in the AGROFOOD database, the user can decide for which products to replace the Armington by a spatial arbitrage approach, also called Spatial Price Equilibrium (SPE) approach. Within SPE, products of different origins are treated as perfect substitutes, i.e., without assuming quality differences by origin as underlying the Armington approach. SPE implies the law of one price such that prices at c.i.f. plus tariff for realized trade flows must be equal. Consequently, the lowest cost provider determines the price level of imports.

The implementation of SPE is challenging as related no-arbitrage conditions are not twice differentiable. They state that trade emerges (is non-zero) if a c.i.f. price plus tariff is equal to the minimum c.i.f. price plus tariff and zero otherwise. Accordingly, a drop in a single c.i.f. price/tariff would imply that all other trade flows disappear. To keep some non-zero flows as a response to such a shock, the related production costs (defines f.o.b.) would need to fall to the point where the minimum bilateral price is reached. This, in turn, defines new minimum prices for other export destination of the supplying region where production costs drop. This mechanism, however, does not work in a detailed CGE model where production costs usually barely react to moderate changes in specific bilateral trade flows. This typically implies that the production cost adjustment response is too low to bring all SPE conditions into equilibrium for an import product market (at least for smaller trade flows), which would leave solely the least cost trade flow at non-zero. Thus, the response of c.i.f. prices to changes in bilaterally traded quantities needs to be modified by introducing a non-linear update mechanism that allows to exceed adjustment ranges found in the standard GTAP model.

A reason for adjustments in import prices relates to the changes in per unit trade cost. However, per unit transport margins and ad-valorem tariffs or equivalents are generally independent of traded quantity (besides for TRQs) in the model. Per unit transport margins are endogenous in the GTAP model, but they depend on price feedback to changes in aggregated trade. Further, the SPE mechanism typically applies to many bilateral flows for a product as GTAP tends to have dense bilateral trade matrices. In the proposed implementation, per unit bilateral transport margins depend on the traded quantities. In reality, such a behaviour in response to higher traded quantity could be explained by longer domestic transport distances covered to add the supply of more firms, or through other impacts on marginal transport costs of increasing trade.

Besides the numerical difficulties, the lack of data not only on trade but also, for example, on trade margins for unobserved (i.e., zero in the benchmark data) trade flows pose a challenge. According to the underlying assumptions, a zero flow occurs if f.o.b. plus transaction costs (= trade margins in the GTAP Data Base) plus tariff exceed the c.i.f. price of the lowest cost importer. Unfortunately, the size of this difference is unknown. Trade databases (TASTE, MacMaps) underlying most global CGE analysis do not report tariffs for non-observed flows and the GTAP Data Base does not comprise transport margins for such zero observation. This requires assumptions, such as using the largest reported applied tariffs, or some empirical relation between transport margins and transport distance.

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Since solving the SPE Module is computationally quite demanding, a pre-solve algorithm was developed which solves solely the SPE market independent from the rest of the CGE model before the full model is solved. This pre-solve algorithm mimics the smoothing functions used in MCP solvers, but allows to solve the model faster and with more stability based on CNS or NLP. The technical implementation including the related equations described above can be found in the CGEBox documentation (Britz, 2021a).

The graphical user interface allows to take the afore-described decisions for the SPE. Figure 2 informs about the graphical implementation and the possible settings. The listed sectors enables the user to choose the involved sectors. Further choices are required regarding the non-linearity (transport margin, or additive CET) and whether pre-solves should be activated.

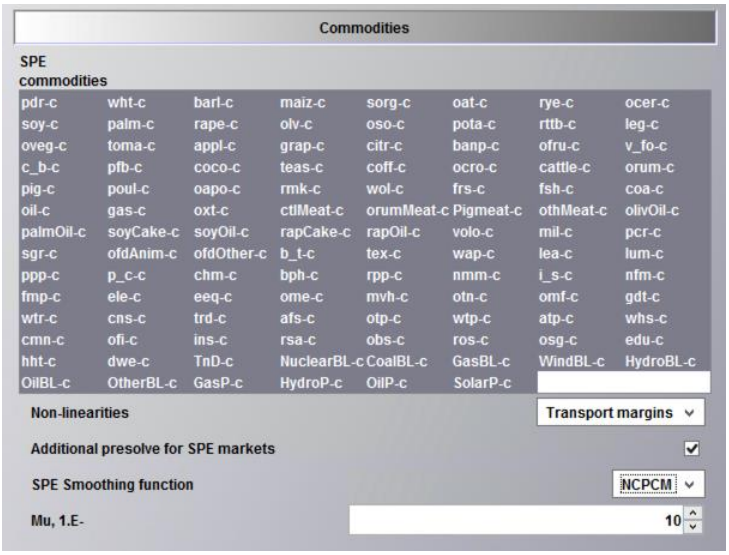

Figure 2. Screenshot of the graphical user interface of CGEBox showing the choice options for the SPE module

This SPE module can also be activated together with the tariff line/data differentiation methods. The following results and discussion section show an example application in the context of the CETA agreement.

EXAMPLE APPLICATION: RESULTS AND DISCUSSION

We provide in the following an example for the combined application of the three above-described methodologies by analysing the CETA agreement with a focus on the dairy sector. To do so, the AGROFOOD database is first re-aggregated to match the sectoral coverage of GTAP V10, with the exception of the dairy sector. This sector maintains a more detailed representation for six differentiated sectors: cheese, butter, skimmed milk powder, whole milk powder, whey and other dairy, see Figure 3. The regions are aggregated to cover Canada, EU and a 'Rest of the world' aggregate. Applying the Tariff Line module, the dairy sectors are matched with the respective HS6/HS8 tariff lines. This detail permits to incorporate a TRQ scheme for 17 different HS8 tariff lines linked to the cheese sector, marked with a yellow box in Figure 3. Being a relatively homogenous product, sugar is chosen to serve as example product for the joint

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implementation of the SPE module. Changes in tariffs as well as in- and out-of-quota tariffs are in line with the CETA agreement and are implemented in a counterfactual scenario. For all sectors, this leads to a reduction in tariffs, in many cases even to a full liberalisation. However, for some sensitive sectors, the changes are smaller. In Canada, this is the case for the dairy (or cheese) sector. For the TRQ of cheese, a reduction applies only for the in-quota tariff which is fully liberalized, while the out-of-quota tariff remains unchanged. The size of the quota is however also extended.

The CETA agreement is analysed in two additional settings, to quantify the impact of using the trade flow differentiations based on the Tariff Line module and of a higher disaggregation of dairy in the full model structure based on the AGROFOOD database. The first setting uses the Tariff Line module to link the standard GTAP V10 data, both with (Split_TL, as depicted in Figure 3) and without the detailed dairy disaggregation offered by AGROFOOD (Dairy_TL, i.e., skipping the second row of Figure 3), to the respective tariff lines and TRQs. Second, the standard GTAP V10 data only is used as basis for the CETA analysis, however here not linked to the Tariff Line module, but shocked with an aggregated tariff shock including one TRQ (Dairy_ST_TRQ) and depicting all tariffs as ad-valorem equivalents (Dariry_ST_AVE). To single out the effect of the SPE module also here a counterfactual is run, applying the Tariff Line module alone to the data set with the disaggregated dairy sectors.

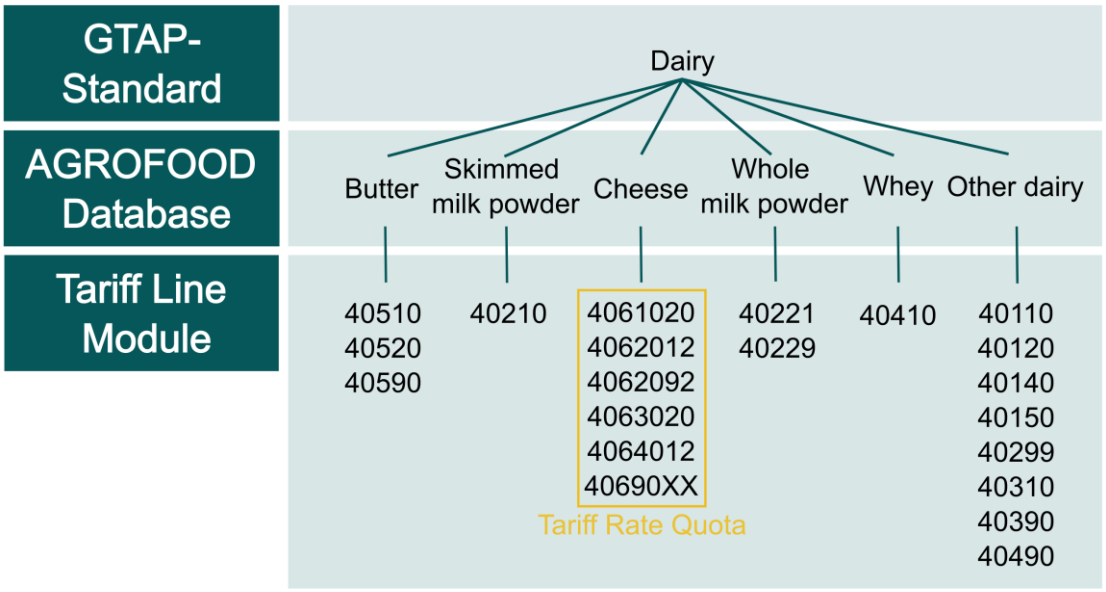

Figure 3. Level of final detail through disaggregation of dairy sector with AGROFOOD and Tariff Line module

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Table 1: Change in Canadian import quantity from EU and in total Canadian exports in response to the CETA Agreement in different model set-ups

	Scenario	Product	Change to base
Imports	Split_TL	Dairy	2%
		Cheese	*6.4%*
		Butter	*0.2%*
		Whey	*6.5%*
	Dairy_TL	Dairy	6.3%
		Cheese	*6.5%*
		Other dairy	*2%*
	Dairy_ST_TRQ	Dairy	0.5%
	Dairy_ST_AVE	Dairy	0.3%
Exports	Split_TL	Dairy	-0.2%
		Cheese	*-0.2%*
		Butter	*-0.2%*
	Dairy_TL	Dairy	-0.2%
	Dairy_ST_TRQ	Dairy	6%
	Dairy_ST_AVE	Dairy	-0.2%

The AGROFOOD differentiation of the dairy sector in combination with the Tariff Line module allows to analyse very specifically which dairy sector is affected by the Free Trade Agreement. This combination (Split_TL) reveals that trade changes are concentrated in the cheese sector, while the other dairy sectors show mainly marginal adjustments in trade, exemplified by the butter sector in Table 1. An exception among the other dairy sectors is whey, which shows a similar effect size as the cheese sector. For comparison, the Tariff Line module without AGROFOOD detail for the dairy sector (Dairy_TL) shows an average increase of Canadian dairy imports from EU, which is close to the effect shown by the combined method (Split_TL) for cheese and whey imports only, as summarised in Table 1. Thus, the average effect of the dairy sectors in the Split_TL setting is more muted, while both settings lead to similar effects for cheese. Taking the tariff lines out (Dairy_ST_TRQ), but keeping the explicit modelling of the TRQ for the aggregated dairy sector, shows a much lower expansion in Canadian dairy imports from EU, while the total Canadian exports of dairy overall increase strongly. The other configurations show slightly decreasing Canadian exports (see Table 1). Aggregating the tariffs to the dairy level and applying the TRQ to this aggregated dairy sector generates misleading results induced by the aggregation bias. It limits all Canadian dairy imports instead of applying the stronger TRQ restriction for cheese products, only. Finally, applying again the standard GTAP V10 Data Base, however, now with Ad-valorem equivalents (Dairy_ST_AVE) of the CETA Agreements shows that results are here again similar to the other scenarios in terms of total Canadian exports. Import changes for the dairy aggregate in Canada are however lowest under this model set up. Changes on macroeconomic indicators such as GDP are marginal in all scenarios and show no significant difference among the methodologies. This model set-up comparison clearly underlines the potential of the combined method (Split_TL) to further reduce the aggregation bias by analyse

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substitution effects on global markets and tariff differentiation of targeted goods, without involving exporters of other (dairy) products.

Table 2: Change in bilateral export quantity and prices of sugar in response to the CETA Agreement when analysed additionally with the SPE module

	Exporter	Change to no SPE
Quantity	Canada	36.47%
	EU	4.42%
Price	Canada	3.05%
	EU	0.95%

Activating the SPE module for sugar in this CETA Tariff Line module setting results in considerably higher Canadian exports of sugar to the EU while also exports from the EU to Canada increase, see Table 2. Prices increase in line with the increased export demand. The effect on all other commodities is minor. Likewise, effects on macroeconomic indicators are again negligible, with only the money metric showing some changes for Canada, where it increases by 1%.

CONCLUSION

The methodologies laid out in this Deliverable show considerable potential for future trade assessments, improving the representation of trade policies and their effects through context specific activation of the modules and disaggregation of the database.

The Tariff Line module and the extended AGROFOOD database add detail for trade representation to overcome aggregation biases by endogenously modelling substitution effects and trade policies at their target level. To deal with the problem of emerging or vanishing trade flows, an SPE module is detailed, which introduces the assumption of homogenous quality for selected goods.

By applying an example CETA shock, this deliverable shows also that the methodologies can be combined in analysis.

PROJECT OUTPUTS ACHIEVED

The Tariff Line module and the GTAP-AGROFOOD database show considerable potential to overcome aggregation bias in the assessments of trade policy changes.

The Spatial Price Equilibrium module enables to depict emerging trade flows.

A combined implementation of the three methods has been successfully carried out.

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