TRQ–HS: A New High-Resolution Quota Module for GTAP-HS

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Abstract

Computable general equilibrium (CGE) models are widely used to assess the economy-wide effects of trade policy reforms. However, tariff-rate quotas (TRQs) are often represented in a simplified way, either through ad-valorem equivalents or at highly aggregated sectoral levels. This may be problematic when quota-based instruments apply to specific products and generate regime-dependent effects that cannot be captured by standard tariff shocks. The issue is particularly relevant today. TRQs remain extensively used on the import side, especially in agricultural and industrial policy, while export restrictions and export quotas are increasingly adopted in strategic sectors such as critical raw materials, fertilizers and clean-technology supply chains. This paper contributes to the literature by developing a new CGE modelling framework that explicitly represents both import and export quotas. The model builds on the GTAP-HS framework, which combines the global consistency of the GTAP model with product-level detail at the HS6 level. Within this structure, we introduce a quota module for imports based on the existing TRQ logic and extend it with a new export-quota module. The resulting framework allows quota regimes, rents and policy wedges to be analysed at the level of product detail at which these measures are implemented. This provides a more suitable tool for evaluating modern trade policies involving both market-access restrictions and strategic export controls.

1 Introduction

Tariff-rate quotas (TRQs) have been a central instrument in agricultural and trade policy since their formalization under the Uruguay Round of multilateral trade negotiations. TRQs combine a relatively low in-quota tariff with a higher, and sometimes prohibitive, out-of-quota tariff applied once imports exceed a predefined quantity threshold. This structure generates a piecewise import demand schedule characterized by different regimes: a non-binding quota regime, a binding quota regime with quota rents, and an above-quota regime in which trade takes place at the higher tariff rate. In CGE models, this type of policy is naturally represented through complementarity conditions, which allow the model to endogenously switch across regimes depending on market conditions.

Although TRQs originated mainly in the context of agricultural trade, they remain widely used in contemporary trade policy. Several countries continue to rely on quota-based instruments to protect domestic markets and sensitive industries. A recent example is the European Union's steel safeguard system, which uses tariff-rate quotas to limit tariff-free imports and impose higher duties once quotas are exceeded (European Commission, 2025a). This policy is explicitly designed to shield the European steel market from global overcapacity and import surges, and it represents the main policy case considered in this study.

Other examples are found in agricultural markets. The European Union maintains TRQs for several agricultural products under its WTO schedule (European Commission, 2025b), while Canada applies TRQs to supply-managed products such as dairy, poultry and eggs (Global Affairs Canada, 2025). The United Kingdom also maintains its own TRQ system after Brexit, including quotas for products such as poultry, beef, cereals, rice, sugar, milk products and eggs (Department for Business and Trade, 2025). The United States also continues to allocate WTO TRQs for products such as raw cane sugar, refined sugar and sugar-containing products (Office of the United States Trade Representative, 2024).

In recent years, quota-based and restriction-based instruments have also become increasingly relevant on the export side. This reflects the growing use of trade policy as a tool to protect strategic sectors, secure domestic supply, and strengthen national positions in technological competition and decarbonization. A particularly important example concerns export restrictions on critical raw materials. According to recent OECD evidence, export restrictions on critical raw materials have increased roughly fivefold since 2009 and remain at historically high levels. OECD data also show that around 16% of global trade in critical raw materials is currently subject to at least one export restriction (OECD, 2026).

China represents one of the most relevant cases in this context. Given its dominant position in the production and refining of several critical minerals, China has progressively developed a system of export controls based on national security considerations and strategic reciprocity. This system has evolved from simple quantitative restrictions toward a more complex licensing regime for dual-use goods and strategic materials. Export controls have been introduced on products such as gallium, germanium and graphite, all of which are relevant for semiconductor, battery and clean-technology supply chains (International Energy Agency, 2023).

Other recent cases point in the same direction. Indonesia has pursued an aggressive downstreaming strategy by restricting and then banning exports of unprocessed nickel ore, with the objective of forcing domestic processing and moving up the value chain (U.S. International Trade Commission, 2021).

Russia has repeatedly imposed export quotas on mineral fertilizers, while India introduced restrictions on rice exports, including a ban on non-basmati white rice in 2023 to preserve domestic availability and contain internal prices (Government of the Russian Federation, 2024).

This policy context creates a clear need for modelling tools capable of evaluating the economic effects of both import and export quotas. CGE models are particularly well suited for this purpose, because they capture the direct effects of trade policy as well as the indirect effects transmitted through production linkages, factor markets, prices, income and welfare. Within the GTAP modelling framework, TRQ modules already exist and have been implemented through complementarity conditions. However, the main limitation is not only the treatment of the quota mechanism itself, but also the level of sectoral aggregation at which the policy is represented.

In practice, both import quotas and export restrictions are usually imposed on very specific products, often identified at the tariff-line or HS6 level. The standard GTAP database, although highly consistent and widely used, is not always detailed enough for these policy applications. In particular, the GTAP sectoral classification aggregates many heterogeneous products into broad sectors, making it difficult to isolate the specific product lines affected by a quota. The GTAP-HS framework (Aguiar et al., 2021) addresses this limitation by combining the GTAP general equilibrium structure with a partial-equilibrium HS-level module, allowing one or more GTAP sectors to be disaggregated into HS6 components while preserving consistency with the GTAP database. This makes GTAP-HS a natural framework for the present contribution. The model allows the analysis of bilateral trade flows at a much more detailed product level, which is crucial when tariffs, quotas or restrictions are applied only to selected HS codes within a broader GTAP sector. The literature has already shown that working at the HS level can reduce aggregation problems and capture heterogeneous responses that would be hidden in a more aggregated database.

The present paper therefore contributes to this literature by integrating the TRQ logic into the GTAP-HS framework. First, it incorporates an import-quota module based on the existing TRQ representation (van der Mensbrugghe, 2019) developed for CGE/GEMPACK applications. This makes it possible to reproduce realistic import TRQ regimes at the HS6 level. Second, the paper extends the framework by introducing a new export-quota module. This second module mirrors the structure of the import-quota mechanism, but applies it to exports and uses the export tax wedge as the relevant policy instrument. In this way, the model can be used not only to study traditional import TRQs, but also export-side restrictions that are increasingly important in markets for strategic sectors.

This contribution fills an important gap in applied trade policy modelling. While the literature includes several examples of equilibrium models with quota mechanisms, and while recent work has emphasized the importance of representing TRQs at the tariff-line level, to the best of our knowledge this is the first

GEMPACK-based GTAP-HS model that allows both import and export quotas to be analysed with sectoral detail down to the HS6 level.

This paper builds on three strands of literature: explicit TRQ modelling in GTAP/GEMPACK (Elbehri and Pearson, 2000), tariff-line and PE/GE approaches for detailed trade policy analysis (Grant et al., 2009);(Narayanan et al., 2010), and recent GTAP-HS applications at the product level (Chepeliev et al., 2021).

A useful comparison is provided by Döbeling, 2022, who studies CETA TRQs between Canada and the European Union using a framework with an endogenous market for quota licenses. In that setting, the allocation of quota licenses across heterogeneous products can affect which commodities gain preferential access to the quota. When several products share the same quota, higher-value commodities may obtain a larger advantage because the absolute tariff saving associated with a license is greater for more expensive products.

A second relevant comparison is Jafari et al., 2021, who develop an explicit TRQ representation within a CGE framework at the tariff-line level. Their results show that modelling TRQs either as ad-valorem equivalents or at the aggregate sectoral level may generate aggregation bias, especially when only part of an aggregate sector is subject to a TRQ or when detailed products face different TRQ regimes. The framework developed in this paper follows the same general motivation: quota-based trade policies should be represented at the level of product detail at which they are actually implemented.

2 Model

In this section, we describe the GTAP-TRQ-HS model used in the simulations presented in Chapter 3. The model combines two extensions of the standard GTAP model (Corong et al., 2017). The starting point is the GTAP-HS model (Aguiar et al., 2021), an extension of the standard GTAP framework which, through a partial equilibrium structure, allows selected GTAP sectors to be disaggregated into HS six-digit sub-sectors. On top of this structure, the GTAP-TRQ framework (van der Mensbrugghe, 2019) is introduced. This framework uses a complementarity mechanism to determine the three possible regimes of the quota.

The GTAP-TRQ-HS extension introduces an additional mechanism, namely the possibility of modelling quotas on exports. While the original TRQ model focuses only on import quotas, this model makes it possible, following the same logic, to introduce an export quota imposed by a country. In practical terms, this implies that the import-side mechanism is associated with the variable linked to TMS, whereas the export-side mechanism is associated with the corresponding export-side variable linked to TXS.

This extension allows the model to represent different export-restriction policies, as discussed in the introduction, while preserving the complementarity-based structure used in the import module. However, one limitation of the model should be highlighted. Although the export-quota module is based on export taxes (TXS), it is constructed by adapting the original import-quota structure, and therefore still relies on VCIFK rather than on VFOBK. This is an important point for the interpretation of the results, even though it is not expected to significantly affect them, given the small difference between PCIFK and PFOBK.

To clarify the role of each component, the remainder of this section is organized as follows. The first part introduces the functioning of the GTAP-HS model and the TRQ extension. The second part presents the new GTAP-TRQ-HS model and the complementarity mechanism underlying both the import and export modules.

2.1 GTAP-HS

The GTAP-HS model represents a modification of the standard GTAP model developed to allow trade policy simulations at a higher level of detail than the one normally provided by the GTAP Data Base. Indeed, although the GTAP Data Base ensures a consistent representation of the world economy and of its sectoral interdependencies, it operates at a level of aggregation that may be too broad when the analysis focuses on trade policy instruments applied to specific tariff lines. This is the case, for example, of tariffs, tariff preferences or quotas, which in practice are often defined at a much more disaggregated level than GTAP sectors.

To address this issue, the GTAP-HS framework allows one or more original GTAP sectors to be disaggregated at the level of the six-digit Harmonized System, that is, at the HS6 level. This disaggregation is carried out through the TASTE utility, which makes it possible to connect the sectoral structure of the GTAP database with more detailed information on trade flows and tariffs. In this way, the model preserves the general equilibrium structure of the standard GTAP model, while at the same time introducing greater granularity in the representation of trade policy.

From this perspective, the model can be interpreted as a hybrid structure between general equilibrium and partial equilibrium. On the one hand, it preserves the fundamental characteristics of CGE models, and therefore the ability to represent interdependencies between sectors, regions, economic agents and markets. On the other hand, it introduces a level of detail closer to that typically used in partial equilibrium models, where trade policy instruments can be represented with greater tariff precision. It is precisely this combination that makes the model particularly useful when the analysis requires distinguishing between products that, although belonging to the same GTAP sector, are subject to different tariff treatments.

The main modifications introduced by this hybrid structure concern above all the specification of demand and supply for goods disaggregated at the HS level.

On the demand side, the model maintains a nested CES structure. Starting from the aggregate absorption of each GTAP good, denoted at level c, demand is allocated across the different HS components, denoted at level k, through a first CES function governed by the elasticity ESUBK(k,r). Subsequently, for each component k, demand is allocated between the domestic good and the imported good through the elasticity ESUBDK. Finally, within imports, demand is distributed across the different regions of origin through the elasticity ESUBMK, thus preserving the two-level Armington structure typical of the GTAP model.

The distinctive element with respect to the standard model concerns the level at which the first Armington nest is implemented. In the standard GTAP model, the choice between domestic and imported goods takes place at the level of the individual agent, distinguishing between households, government, firms and investment. In the GTAP-HS model, instead, this choice is implemented at the aggregate national level. This choice allows the variables defined at the HS level to be connected more directly with the corresponding aggregate variables of the GTAP model, reducing the complexity of the extension and making the link between the two levels of the model easier to manage.

On the supply side, the mechanism follows an analogous logic. Aggregate production defined at level c is distributed across the different HS components through a CET structure, governed by the elasticity ETRAK. In this case, the model represents the possibility that production of the original GTAP sector is transformed into the different components k, according to an allocation logic consistent with the underlying production structure. Each HS component is then allocated between the domestic market and exports following the standard structure of the model, thus preserving the link between production, domestic sales and sales on foreign markets.

A crucial aspect of the GTAP-HS architecture is represented by the so-called bridging equations, that is, the linking equations that ensure consistency between the variables defined at the HS level and the corresponding aggregate variables of the GTAP model. These equations constrain the aggregate variables of the standard model to be equal to the weighted sum of the corresponding variables defined at level k. In other words, they ensure that what happens at the disaggregated level is fully consistent with the aggregate representation of the model.

The bridging equations cover the main value and price variables of bilateral trade, ensuring that the activation of the HS module does not generate inconsistencies in the accounting balances of the database. As a result, the GTAP-HS model is able to combine two requirements that, without this structure, would be difficult to reconcile: on the one hand, preserving the macro-sectoral and accounting consistency of the GTAP model; on the other hand, introducing a sufficient level of detail to analyse trade policy instruments applied to specific tariff lines. It is precisely this feature that makes the model a suitable basis for integration with the TRQ module, since tariff-rate quotas are often defined at the product level and therefore require a more disaggregated representation than the one provided by the standard model.

2.2 GTAP-TRQ

The GTAP-TRQ model represents an extension of the standard GTAP model aimed at explicitly incorporating the functioning of tariff-rate quotas. As already discussed in the introduction, a TRQ cannot be treated as a simple tariff, since it combines a tariff component with a quantitative constraint. Within a given import quota, a reduced tariff, defined as the in-quota tariff, is applied, while beyond that level a higher tariff, defined as the out-of-quota tariff, becomes relevant.

From a modelling perspective, this structure introduces a specific difficulty: the model must be able to determine endogenously the regime in which each trade flow is located. The quota may be non-binding, it may be exactly binding and generate a quota rent, or it may be exceeded, making the out-of-quota tariff relevant. The transition across these regimes is not continuous and cannot be fully represented through the log-linearized equations of the standard model alone.

For this reason, the solution adopted in the TRQ literature, and also followed in this study, is the use of mixed complementarity programming (MCP). This approach allows the model to select endogenously the active regime, depending on the relationship between the observed trade flow and the quota level.

Since the objective of this work is to embed the TRQ module within the broader GTAP-HS framework, the technical description of the mechanism is developed in the following section, where the structure of the GTAP-TRQ-HS model and the extension introduced on the export-quota side are analysed.

2.3 GTAP-TRQ-HS

The model presented in this work integrates three levels of complexity within a single framework: the sectoral disaggregation at the Harmonized System level, which is specific to the GTAP-HS model; the modelling of tariff-rate quotas on imports, derived from the TRQ module; and an original extension which introduces a quota mechanism on exports, here referred to as the ETQ module, or Export Tariff-Rate Quota.

All three levels operate exclusively on the set of disaggregated commodities, COMMK, that is, on the HS goods that represent the disaggregated components of the original GTAP sectors. This is the distinctive feature compared with previous implementations. While in the model developed by (van der Mensbrugghe, 2019) the TRQ module operates on the set of standard sectors, COMM, the present framework brings the quota logic — both on imports and on exports — directly to the HS6 level. This makes it possible to capture more precisely the tariff heterogeneity that characterizes TRQ systems in the real world.

The starting point is the set COMMK, which contains the commodities disaggregated at the HS level and is defined within the GTAP-HS framework. Each element k of COMMK is associated with a unique aggregate sector c of COMM through the mapping MAPKC. This mapping makes it possible to preserve consistency between the HS level and the GTAP level through the bridging equations described above.

To manage the complementarity conditions efficiently on a restricted subset of bilateral flows, the model introduces a Cartesian product of sets. The set KOMSRC is defined as the product COMMK $\times$ REG, while KOMSRCDST is defined as the product KOMSRC $\times$ REG. This generates a set of n-tuples (k,s,d)(k,s,d)(k,s,d) covering all possible bilateral flows at the HS level. Six projection mappings then allow the model to recover the individual commodity and regional indices from the n-tuples, making it possible to write the complementarity conditions in indexed form over the set of n-tuples.

Set

KOMSRC = COMMK x REG ;

KOMSRCDST = KOMSRC x REG ;

Mapping

(**project**) KS2K **from** KOMSRC **to** COMMK ;

(**project**) KS2S **from** KOMSRC **to** REG ;

(**project**) KSD2D **from** KOMSRCDST **to** REG ;

(**project**) KSD2KS **from** KOMSRCDST **to** KOMSRC ;

Mapping KSD2S **from** KOMSRCDST **to** REG ;

Formula (**all**,n,KOMSRCDST) KSD2S(n) = KS2S(KSD2KS(n)) ;

Mapping KSD2K **from** KOMSRCDST **to** COMMK ;

Formula (**all**,n,KOMSRCDST) KSD2K(n) = KS2K(KSD2KS(n)) ;

This first mapping is identical for the two modules, import and export, and the partitioning logic is also analogous in both cases. The set TRQSET contains the n-tuples for which the import quota XMQ is strictly positive, while its complement, NTRQSET, contains all the remaining flows. Similarly, ETRQSET contains the n-tuples for which the export quota XEQM is positive, while NETRQSET represents its complement. This bipartition ensures that the additional equations in the TRQ and ETQ modules are defined only over the relevant nodes, thereby limiting the computational cost.

Set TRQSET # *Imports with TRQs* #

= (**all**,n,KOMSRCDST: XMQ(KSD2K(n),KSD2S(n),KSD2D(n)) > 0) ;

! Define the complement !

Set NTRQSET # *Normal imports* # = KOMSRCDST - TRQSET ;

Set ETRQSET # *Exports with ETQs* #

= (**all**,n,KOMSRCDST: XEQM(KSD2K(n),KSD2S(n),KSD2D(n)) > 0) ;

Set NETRQSET # *Normal exports* # = KOMSRCDST - ETRQSET ;

2.3.1 TRQ module: Import quotas

The TRQ module implements tariff-rate quotas on bilateral import flows for commodities k belonging to COMMK. Its structure is conceptually analogous to that of the standard GTAP-TRQ model, but it is indexed over the HS set rather than over the aggregate COMM set.

The module introduces three link variables that connect the levels-based module with the main body of the GTAP-HS model, which is expressed in percentage changes.

Variable (**LINEAR_VAR**=tmsk) (**all**,k,COMMK)(**all**,s,REG)(**all**,d,REG)

TMS_Lk(k,s,d) # *End-user tariff in levels* # ;

Variable (**LINEAR_VAR**=pcifk) (**all**,k,COMMK)(**all**,s,REG)(**all**,d,REG)

PCIF_Lk(k,s,d) # *Level of PCIF* # ;

Variable (**LINEAR_VAR**=qxsk)

(**all**,k,COMMK)(**all**,s,REG)(**all**,d,REG)

QXS_Lk(k,s,d) # *Export HS6 k da s a d (levels)* # ;

The variable TMS_Lk represents the level of the tariff perceived by the importer and is declared as a linear variable linked to the percentage-change variable tmsk. Similarly, PCIF_Lk represents the level of the import price and is linked to pcifk, while QXS_Lk represents the level of import volumes and is linked to qxsk.

In the same way, the module introduces three endogenous variables and four exogenous variables. The endogenous variables are the quota rent, the value of the quota accruing to the exporter, and total quota rents.

The exogenous variables are the in-quota tariff, the out-of-quota tariff, the quota quantity, and the exporter's share of the quota rent.

! Endogenous variables !

Variable (**Levels**,**Change**) (**all**,k,COMMK)(**all**,s,REG)(**all**,d,REG)

QUOTA_RENT(k,s,d) # *Quota rent* # ;

Variable (**Levels**,**change**) (**all**,k,COMMK)(**all**,s,REG)(**all**,d,REG)

QRENT_X(k,s,d) # *Value of quota rent that accrues to the exporter* # ;

Variable (**LEVELS**,**change**) (**all**,s,REG)

TQRENT_X(s) # *Total quota rents (over all TRQ flows) captured by exporter* # ;

! Exogenous variables !

Variable (**all**,k,COMMK)(**all**,s,REG)(**all**,d,REG)

TMS_IN(k,s,d) # *Power of in-quota tariff* # ;

Variable (**all**,k,COMMK)(**all**,s,REG)(**all**,d,REG)

TMS_OUT(k,s,d) # *Power of out-of-quota tariff* # ;

Variable (**all**,k,COMMK)(**all**,s,REG)(**all**,d,REG)

XMQ(k,s,d) # *Quota quantity* # ;

Variable (**all**,k,COMMK)(**all**,s,REG)(**all**,d,REG)

QRSHR_X(k,s,d) # *Exporter's share of the quota rent* # ;

The initialization follows a multi-step procedure. The border price PCIF_Lk is initialized at 1. The import volume QXS_Lk is then calculated as the ratio between the CIF value of imports, VCIFk, and the initial border price. The coefficient VCIFWGT, which represents the base quantity weight, is set equal to QXS_Lk in the benchmark year and is used to express the quota as an index. This ensures that the complementarity condition is written in dimensionless terms, improving numerical convergence.

The initial effective tariff TMS_Lk is calculated as the ratio between the value of imports at basic prices, VMSBk, and the CIF value, VCIFk. For flows that are not subject to a TRQ, the in-quota and out-of-quota tariffs are both set equal to the initial effective tariff, ensuring continuity with the ordinary tariff regime. The variables TMS_OUT and TMS_IN are then initialized by distinguishing the possible cases in which the TRQ module is active or not.

! Initialize the levels and convert the quota to an index !

Formula (**Initial**) (**all**,k,COMMK)(**all**,s,REG)(**all**,d,REG) PCIF_Lk(k,s,d) = 1 ;

Formula (**Initial**) (**all**,k,COMMK)(**all**,s,REG)(**all**,d,REG) QXS_Lk(k,s,d) = VCIFk(k,s,d) / PCIF_Lk(k,s,d) ;

Formula (**Initial**) (**all**,k,COMMK)(**all**,s,REG)(**all**,d,REG) VCIFWGT(k,s,d) = QXS_Lk(k,s,d) ;

Formula (**Initial**) (**all**,k,COMMK)(**all**,s,REG)(**all**,d,REG) XMQ(k,s,d) = XMQ(k,s,d) * QXS_Lk(k,s,d) / VCIFWGT(k,s,d) ;

Zerodivide off ;

Zerodivide (zero__by__zero) default 0;

Formula (**Initial**) (**all**,k,COMMK)(**all**,s,REG)(**all**,d,REG) TMS_Lk(k,s,d) = VMSBk(k,s,d) / VCIFk(k,s,d) ;

Formula (**Initial**) (**all**,k,COMMK)(**all**,s,REG)(**all**,d,REG)

TMS_OUT(k,s,d) = **if**[TRQFLAG(k,s,d) = 0, TMS_Lk(k,s,d)] + **if**[TRQFLAG(k,s,d) <> 0, TMS_OUT(k,s,d)] ;

Formula (**Initial**) (**all**,k,COMMK)(**all**,s,REG)(**all**,d,REG)

TMS_IN(k,s,d) = **if**[TRQFLAG(k,s,d) = 0, TMS_Lk(k,s,d)] + **if**[TRQFLAG(k,s,d) <> 0, TMS_IN(k,s,d)] ;

Zerodivide (zero_by_zero) off;

Before introducing the complementarity condition, it is necessary to define additional variables indexed over the n-tuple. These are: the final tariff perceived by the importer over the set TRQSET, denoted by TMS_LNk(n); the final exogenous tariff over the complementary set, denoted by TMS_LXk(n); the in-quota tariff for trade flows subject to a TRQ, TMS_INN(n); and the out-of-quota tariff, again defined over TRQ trade flows, TMS_OUTN(n).

Variable (**all**,n,TRQSET) TMS_LNk(n) # *Endogenous tariffs* #;

Formula & Equation E_TMS_LNk (**all**,n,TRQSET)

TMS_LNk(n) = TMS_Lk(KSD2K(n),KSD2S(n),KSD2D(n)) ;

Variable (**all**,n,NTRQSET) TMS_LXk(n) # *Exogenous tariffs* # ;

Formula & Equation E_TMS_LXk (**all**,n,NTRQSET)

TMS_LXk(n) = TMS_Lk(KSD2K(n),KSD2S(n),KSD2D(n)) ;

Variable (**all**,n,TRQSET) TMS_INN(n) # *In-quota tariff for TRQ trade* #;

Formula (**Initial**) (**all**,n,TRQSET) TMS_INN(n) = TMS_IN (KSD2K(n),KSD2S(n),KSD2D(n)) ;

Variable (**all**,n,TRQSET) TMS_OUTN(n) # *Out-quota tariff for TRQ trade* #;

Formula (**Initial**) (**all**,n,TRQSET) TMS_OUTN(n) = TMS_OUT(KSD2K(n),KSD2S(n),KSD2D(n)) ;

2.3.2 ETQ module: Export quotas

The ETQ module represents the original extension of the present framework with respect to previous implementations. It introduces a system of export quotas with a two-tier tariff structure, symmetric to the import-side TRQ module but applied to export taxes (txsk). While import TRQs are typically introduced by the importing country to manage foreign competitive pressure, export quotas, or ETQs, may be introduced by the exporting country to control export volumes, for example for reasons related to food security, natural resource management, or obligations arising from bilateral trade agreements.

The structure of the ETQ module closely replicates that of the TRQ module, with the necessary adaptations for the export dimension. The link variable TXS_Lk(k,s,d) represents the level of the effective export tax and is declared as a linear variable linked to txsk. The exogenous parameters of the module are: TXS_IN(k,s,d), the level of the in-quota tax, that is, the tax applied to exports within the quota; TXS_OUT(k,s,d), the out-of-quota tax, namely the higher tax applied to exports exceeding the quota; XEQM(k,s,d), the level of the export quota expressed as an index relative to initial exports; and EQRSHR_X(k,s,d), the share of the quota rent captured by the exporter.

A modelling limitation should be made explicit at this point. In a fully export-side formulation, the effective export tax would naturally be initialized using the FOB-side wedge, that is, the ratio between VFOBk and VXSBk. However, the present implementation adapts the original import-side TRQ structure to the export side. For this reason, the ETQ module uses the same quantity and valuation basis as the TRQ module: the trade volume QXS_Lk is initialized from VCIFk and PCIF_Lk, and the base weight EVCIFWGT is defined consistently with this CIF-based quantity measure. Consequently, TXS_Lk is initialized as VMSBk/VCIFk, not because this is the pure FOB-based export-tax power, but because it preserves consistency with the existing GTAP-HS/TRQ structure used to impose the complementarity condition.

The initialization of the ETQ module follows the same logic as the TRQ module. The coefficient EVCIFWGT is initialized with the same value as QXS_Lk, since export and import flows are valued at CIF prices in the GTAP-HS database. The quota XEQM is converted into an index by dividing it by the base weight EVCIFWGT. The initial effective export tax TXS_Lk is calculated as the ratio VMSBk/VCIFk.

2.3.3 Complementarity mechanism

The endogenous management of quota regimes — both for the TRQ module and for the ETQ module — represents the technical core of the framework and is based on mixed complementarity programming. In general, mixed complementarity programming extends standard systems of equations by allowing inequalities and orthogonality conditions to be incorporated. An MCP condition links a variable to an expression through the following structure: the variable is bounded within an interval [lb,ub]; if the variable lies strictly inside this interval, the associated expression must be equal to zero; if the variable is at its lower bound, the expression may be non-negative; and if the variable is at its upper bound, the expression may be non-positive. This structure makes it possible to model endogenous regime switching without having to specify ex ante which regime is active.

In the context of quotas, the complementarity condition links the effective tariff, or tax, to the gap between the quota level and the volume of imports or exports. The lower and upper bounds of the variable are, respectively, the in-quota tariff and the out-of-quota tariff.

Analytically, let M_{hs} denote the import volume for a specific HS line, and let XMQ denote the corresponding exogenous quota level. The complementarity condition determines the effective power of the tariff, TMS_Lk, which is bounded between the in-quota tariff, TMS_IN, and the out-of-quota tariff, TMS_OUT. Depending on the relationship between import demand and the quota level, three regimes may arise:

- **In-quota regime.** If import volume is below the quota level,

  $$M_{hs} < XMQ,$$

  the quota is non-binding. In this case, the effective tariff is equal to the lower bound:

  $$\text{TMS\_Lk} = \text{TMS\_IN}.$$

- **Binding-quota regime.** If imports exactly reach the quota level,

  $$M_{hs} = XMQ,$$

  the quota constraint binds and a scarcity rent is generated. In this regime, the effective tariff is endogenously determined by the complementarity condition and lies between the in-quota and out-of-quota rates:

  $$\text{TMS\_IN} < \text{TMS\_Lk} < \text{TMS\_OUT}.$$

- **Out-of-quota regime.** If import demand is sufficiently high to exceed the quota,

  $$M_{hs} \geq XMQ,$$

  the effective tariff reaches its upper bound:

  $$\text{TMS\_Lk} = \text{TMS\_OUT}.$$

TRQ complementarity For the TRQ module, the complementarity condition is defined over the set TRQSET, which contains the n-tuples subject to an import quota. The variable TMS_LNk(n) — that is, the tariff level associated with the n-tuple n — is bounded within the interval [TMS_INN(n),TMS_OUTN(n)], namely between the in-quota and the out-of-quota tariff. The expression evaluated by the complementarity condition is the gap between the quota level and normalized import volumes:

$$\text{XMQ}(k, s, d) - \frac{\text{QXS\_Lk}(k, s, d)}{\text{VCIFWGT}(k, s, d)}$$

.

The logic of the three regimes is the following. In the first regime, imports are below the quota: the gap is positive, the tariff is set at its lower bound, TMS_IN, and the quota is not binding. In the second regime, imports exactly reach the quota: the gap is zero and the tariff can take any value within the interval [TMS_IN,TMS_OUT], determining the quota premium required to equilibrate demand and supply. In the third regime, imports exceed the quota: the gap is negative, the tariff is set at its upper bound, TMS_OUT, and imports above the quota are subject to the out-of-quota tariff.

The normalization of import volumes by VCIFWGT ensures that the comparison between the quota and import volumes is expressed as an index relative to the benchmark year, avoiding numerical problems related to the absolute scale of trade values.

Complementarity

(**Variable** = TMS_LNk, **Lower_Bound** = TMS_INN, **Upper_Bound** = TMS_OUTN) TRQK

(**all**,n,TRQSET)

XMQ(KSD2K(n),KSD2S(n),KSD2D(n))

- QXS_Lk(KSD2K(n),KSD2S(n),KSD2D(n)) / VCIFWGT(KSD2K(n),KSD2S(n),KSD2D(n))
;

ETQ complementarity For the ETQ module, the complementarity condition is structurally identical to that of the TRQ module, but it is applied to export taxes. The variable TXS_LNk(n) — that is, the level of the effective export tax for the n-tuple n — is bounded within the interval [TXS_INN(n),TXS_OUTN(n)]. The expression evaluated by the complementarity condition is the gap:

$$\mathrm{XEQM}(k,s,d) - \frac{\mathrm{QXS\_Lk}(k,s,d)}{\mathrm{EVCIFWGT}(k,s,d)}$$

where XEQM is the export quota expressed as an index.

The economic interpretation of the three regimes is symmetric, but with a different perspective. In the first regime, exports are below the allowed quota: the tax is set at its minimum value, TXS_IN, the constraint is not binding and no rents are generated. In the second regime, exports exactly reach the quota limit: the constraint is binding, a rent is generated and the effective tax rises above TXS_IN. In the third regime, exports exceed the quota: the effective tax reaches its maximum value, TXS_OUT, and is fully applied to exports above the quota.

From the perspective of the exporting country, a binding ETQ is equivalent to a form of quantitative discipline that reallocates rents within the system. Differently from an import-side TRQ, where part of the rent may accrue to the foreign exporter, under an ETQ the rent tends to remain within the economy imposing the quota, with EQRSHR_X determining its distribution across agents.

Complementarity

(**Variable** = TXS_LNk, **Lower_Bound** = TXS_INN, **Upper_Bound** = TXS_OUTN) ETQK

(**all**,n,ETRQSET)

XEQM(KSD2K(n),KSD2S(n),KSD2D(n))

- QXS_Lk(KSD2K(n),KSD2S(n),KSD2D(n)) / EVCIFWGT(KSD2K(n),KSD2S(n),KSD2D(n))
;

2.3.4 Rents and changes to the income equation

When the quota is binding, a rent is generated. This rent is equal to the difference between the effective tariff and the in-quota tariff, multiplied by the border price and by the quota volume, adjusted by the base weight. Formally, the quota rent QUOTA_RENT(k,s,d) is defined as the product of the tariff differential (TMS_Lk-TMS_IN)(TMS_Lk - TMS_IN)(TMS_Lk-TMS_IN), the border price PCIF_Lk, the quota level XMQ, and the base weight VCIFWGT.

The share of the rent captured by the exporter, QRENT_X(k,s,d), is equal to the total rent multiplied by the exogenous parameter QRSHR_X(k,s,d), which represents the fraction of the rent transferred to the exporter. The variable TQRENT_X(s) aggregates the rents captured by the exporter across all TRQ flows and all destinations, and is used to adjust the income equation.

Formula & Equation E_QUOTA_RENTk

(**all**,k,COMMK)(**all**,s,REG)(**all**,d,REG)

QUOTA_RENT(k,s,d) = (TMS_Lk(k,s,d) - TMS_IN(k,s,d)) * PCIF_Lk(k,s,d) * XMQ(k,s,d) * VCIFWGT(k,s,d) ;

Formula & Equation E_QRENTXk

(**all**,k,COMMK)(**all**,s,REG)(**all**,d,REG)

QRENT_X(k,s,d) = QRSHR_X(k,s,d) * QUOTA_RENT(k,s,d) ;

Formula & Equation E_TQRENT_X (**all**,s,REG)

TQRENT_X(s) = **sum**(k,COMMK, **sum{**d,REG, QRENT_X(k,s,d)**}**) ;

The same applies to the ETQ module:

Formula & Equation E_EQUOTA_RENTk

(**all**,k,COMMK)(**all**,s,REG)(**all**,d,REG)

EQUOTA_RENT(k,s,d) = (TXS_Lk(k,s,d) - TXS_IN(k,s,d))

* PCIF_Lk(k,s,d) * XEQM(k,s,d) * EVCIFWGT(k,s,d) ;

Formula & Equation E_EQRENTXk

(**all**,k,COMMK)(**all**,s,REG)(**all**,d,REG)

EQRENT_X(k,s,d) = EQRSHR_X(k,s,d) * EQUOTA_RENT(k,s,d) ;

Formula & Equation E_TEQRENT_X (**all**,s,REG)

TEQRENT_X(s) = **sum**(k,COMMK, **sum{**d,REG, EQRENT_X(k,s,d)**}**) ;

The activation of the TRQ module requires two modifications to the equations of the main model. The import tax ratio equation, E_del_taxrimp, is replaced by a version that subtracts from regional income the share of quota rents captured by the exporter. This adjustment is necessary because the log-linearized model calculates tariff revenues using the effective tariff tmsk, which, through the variable TMS_Lk, also includes the quota premium. By subtracting the foreign share of the rent, the model obtains the correct accounting of government tax revenue, separately from quota rents.

The regional income equation, E_y, is also extended by adding the term related to the TRQ rents captured by the exporter for country s.

Equation E_del_taxrimp_full

 # change in ratio of import tax payments to regional income (TRQ + ETQ) #

(**all**,d,REG)

100.0 * INCOME(d) * del_taxrimp(d) + TAXRIMP(d) * y(d)

= **sum{**c,COMM, **sum{**s,REG, VMSB(c,s,d) * [tm(c,d) + tms(c,s,d)]

+ MTAX(c,s,d) * [pcif(c,s,d) + qxs(c,s,d)]**}}**

- **sum{**k,COMMK,**sum{**s,REG, 100*c_QRENT_X(k,s,d)**}}** ;

Equation E_y

 # regional income = primary factors + indirect taxes + TRQ rents + ETQ rents #

(**all**,r,REG)

INCOME(r) * y(r)

= FY(r) * fincome(r)

+ 100.0 * INCOME(r) * del_indtaxr(r)

+ INDTAX(r) * y(r)

+ 100 * c_TQRENT_X(r) *! TRQ import rents !*

+ 100 * c_TEQRENT_X(r) *! ETQ export rents !*

+ INCOME(r) * incomeslack(r) ;

3 Policy Exercise

To illustrate the functioning of the TRQ-HS model, the following sections present three different groups of policy scenarios. The database used in the simulations disaggregates two original GTAP sectors, i_s and nfm, into several HS codes, which are then reorganized into five broader product groups: fleet, long, rail, pipes, and nfm_760200. The disaggregation structure is reported in the following table. The reason for choosing these codes is justified by the European safeguard measure for the European steel industry; consequently, the initial scenarios reflect part of Europe's protectionist policy.

Table 1: HS codes used in the policy exercise

Group	HS6 list
Flat	720810, 720825, 720826, 720827, 720836, 720837, 720838, 720839, 720840, 720851, 720852, 720853, 720854, 720915, 720916, 720917, 720918, 720925, 720926, 720927, 720928, 720990, 721011, 721020, 721030, 721041, 721049, 721061, 721069, 721070, 721090, 721114, 721119, 721123, 721129, 721190, 721220, 721225, 721230, 721240, 721250, 721260, 721911, 721912, 721921, 721931, 721932, 722011, 722012, 722020, 722519, 722530, 722540, 722550, 722591, 722592, 722599, 722619, 722620, 722691, 722699
Long	721310, 721320, 721420, 721430, 721491, 721499, 721510, 721550, 721590, 721610, 721621, 721622, 721631, 721632, 721633, 721640, 721650, 721699, 721710, 722100, 722110, 722211, 722219, 722221, 722230, 722810, 722820, 722830, 722850, 722860, 722870, 722880
Rail	730110, 730210, 730290
Pipes	730411, 730419, 730422, 730423, 730424, 730431, 730439, 730441, 730449, 730451, 730459, 730490, 730511, 730512, 730519, 730520, 730611, 730619, 730621, 730629, 730630, 730640, 730650, 730661, 730669, 730690
Nfm760200	760200
Other I_S	The remaining I_S codes
Other nfm	The remaining nfm codes

The GTAP-HS framework also requires the specification of three additional demand elasticities for each HS component: ESUBK, ESUBDK, and ESUBMK. In the absence of product-specific estimates at the HS level, the standard approach would be to assign to each HS component the elasticity of the corresponding parent GTAP sector. However, given the importance of substitution elasticities in a model with this level of disaggregation, this study uses the recent HS6-level Armington elasticity estimates provided by Fontagné, Guimbard and Orefice (2019). This makes it possible to account more explicitly for the heterogeneity in trade responses across different components of the same aggregate sector. The elasticities used in the simulations are reported in Appendix II, Table 5-8.

The policy scenarios are organized as follows.

Scenarios SCN1–SCN3 introduce an import quota on commodities k for the bilateral trade flow from China to Western Europe. The three scenarios differ in the restrictiveness of the quota, which is progressively set at 70%, 50%, and 30% of the benchmark level. The objective is to identify the tariff level that eliminates out-of-quota trade, while showing the effects in terms of trade diversion, tariff heterogeneity across HS components, and the differences between a quota imposed on the China–Western Europe flow and an alternative source–destination pair.

Scenarios SCN4–SCN6 represent the symmetric exercise on the export side. In this case, an export quota is imposed on the same group of commodities k for the trade flow from China to Southeast Asia. As in the previous set of scenarios, the quota is progressively tightened from 70% to 50% and then to 30%, allowing the analysis to show how the export-side mechanism operates and how the implied tax response differs across HS sectors.

Finally, SCN7 we impose an import quota on imports from the East Asia aggregate originating in China. The quota rate is set at 50%. This allows us to compare the results between in-quota and out-of-quota tariffs in the case of the EU or the East Asia aggregate.

3.1 Scenarios SCN1–SCN3

This first group of scenarios imposes an import quota on European imports from China for the HS product group reported in Table 1. The structure of the simulation is progressive: in SCN1 the quota is set at 70% of the initial level of imports, in SCN2 at 50%, and in SCN3 at 30%. The objective of the exercise is to identify, for each disaggregated product, the level of the effective tariff that is able to eliminate out-of-quota trade. In this way, the model does not impose a uniform tariff from outside, but endogenously determines the level of TMS_Lk required to make the quota binding and close the excess trade flow.

A further exercise is then constructed by replicating the same policy as in SCN2, but applying it to a different bilateral trade flow. In this case, the quota is no longer imposed on imports from China to Europe, but on the East Asia–Europe flow. This comparison allows us to highlight a second relevant feature of the model, namely the possibility of observing how the same trade policy may produce different effects depending on the geographical structure of trade and on the partner affected by the measure.

The first result that emerges concerns the heterogeneity of the tariff levels required to eliminate out-of-quota trade. As shown in Figure 1, in SCN2, where the quota is equal to 50% of the initial level, the effective tariffs are not uniform across the different HS components. The values of TMS_Lk, expressed as ad valorem equivalent tariffs, range from 4.45% for rail to 7.10% for pipes. The other products also show different values: flat requires a tariff of 5.93%, long 5.64%, while NFM_760200 reaches 6.65%.

This heterogeneity represents one of the main results of the exercise. If the same policy had been applied at the aggregate GTAP level, the model would have returned a single average tariff for the whole sector, thereby losing the information related to the different responses of the individual HS components. By contrast, the TRQ-HS model shows that, for the same quota reduction, the tariff level required to eliminate out-of-quota trade changes significantly across products belonging to the same aggregate sector.

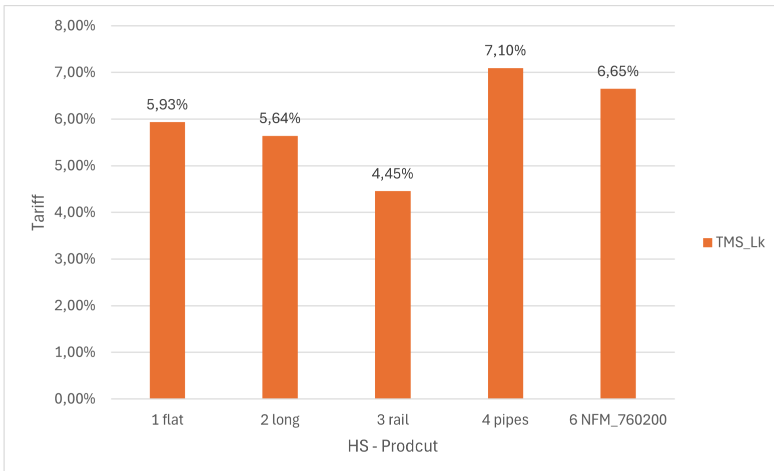

Figure 1: Level of tariff quota that eliminates imports out-of-quota in scenario SCN2

The reason for this difference is mainly related to the substitution elasticities used in the model. Products characterized by a lower elasticity require a higher tariff to obtain the same reduction in the trade flow, since demand is less responsive to changes in relative prices. This is the case of pipes, which shows the highest tariff value, equal to 7.10%. Conversely, when the elasticity is higher, the trade flow reacts more strongly to the price change, and therefore a lower tariff is sufficient to eliminate out-of-quota trade. In this sense, the case of rail, with a tariff equal to 4.45%, represents the opposite result.

It is important to clarify that the variable reported here is TMS_Lk, that is, the level of the effective tariff perceived by the importer at the HS level. It does not simply represent an exogenous tariff imposed in the scenario, but the endogenous value generated by the complementarity mechanism of the TRQ module. In other words, TMS_Lk incorporates the premium required to make the quantitative constraint consistent with the new equilibrium of the model. For this reason, its heterogeneity across products provides a direct measure of the different intensity with which the quota affects each HS trade flow.

Figure 2 extends the previous result by comparing the tariff levels required to eliminate out-of-quota trade across the three import-quota scenarios. As expected, the more restrictive the quota becomes, the higher the effective tariff required to close the excess trade flow. Moving from a quota equal to 70% of benchmark imports to 50% and then to 30%, TMS_Lk increases for all HS components.

However, the increase is not homogeneous across products. The ranking observed in SCN2 is broadly preserved across the three scenarios. pipes always requires the highest tariff, rising from 3.56% under the 70% quota to 7.10% under the 50% quota and 12.67% under the 30% quota. By contrast, rail remains the product requiring the lowest tariff adjustment, increasing from 2.24% to 4.45% and then to 7.89%.

This confirms that the restrictiveness of the quota affects the overall magnitude of the tariff response, while the heterogeneity across HS components is mainly driven by the product-specific structure of substitution. In other words, the model does not only show that a tighter quota requires a higher tariff equivalent, but also that this tariff equivalent differs systematically across products within the same aggregate sector.

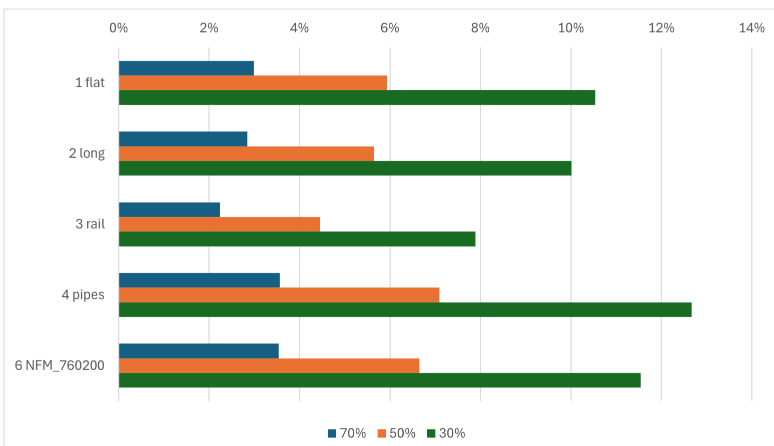

Figure 2: Level of tariff quota that eliminates imports out-of-quota in all scenarios

Another way to understand the response of the model to the import-quota shock is to look at trade diversion. For this reason, Table 2 reports the percentage changes, relative to the benchmark data, in European imports from alternative source regions under the most restrictive scenario, where the quota is set at 30% of the initial China–Europe trade flow.

The results show that the import restriction imposed on China generates a positive reallocation of European demand toward other suppliers. Since the only bilateral flow directly affected by the policy is the China–Europe flow, European importers can partially compensate for the reduction in Chinese imports by increasing purchases from other regions. This is the standard trade diversion mechanism: the quota does not reduce import demand uniformly across all partners, but changes the geographical composition of imports.

	1 Oceania	3 jpn	4 EastAsia	5 SEAsia	6 SouthAsi	7 mex	8 NAmeric	9 LatinAme	10 gbr	11 WestEu	12 tur	13 MENA	14 SSA	15 RestofW
1 flat	2,13%	2,17%	2,13%	2,16%	2,06%	2,14%	2,12%	2,12%	1,88%	1,56%	1,95%	2,11%	2,16%	1,98%
2 long	1,85%	1,86%	1,89%	1,91%	1,82%	1,82%	1,80%	1,82%	1,59%	1,35%	1,73%	1,81%	1,87%	1,68%
3 rail	1,37%	1,41%	1,46%	1,46%	1,45%	1,38%	1,37%	1,37%	1,28%	1,06%	1,36%	1,37%	1,41%	1,39%
4 pipes	1,01%	1,00%	1,02%	1,01%	1,01%	1,00%	0,99%	0,99%	0,94%	0,85%	0,91%	1,00%	1,01%	0,94%
6 NFM_760	0,24%	0,21%	0,23%	0,23%	0,18%	0,21%	0,19%	0,17%	0,16%	0,07%	0,12%	0,18%	0,19%	0,10%

Table 2: Heatmap with imports from EU in % change with respect to BAU

The magnitude of this effect is not homogeneous across HS components. The strongest diversion appears for flat, where imports from most alternative suppliers increase by around 2%. The effect is slightly lower for long, with increases generally between 1.6% and 1.9%, and for rail, where the increase is around 1.3%–1.5%. By contrast, the response is more limited for pipes, close to 1%, and particularly small for NFM_760200, where the increase remains below 0.25% for all source regions.

This pattern confirms that the response to the quota depends not only on the intensity of the restriction, but also on the characteristics of each HS product. Products for which alternative suppliers can more easily replace Chinese imports show stronger trade diversion. Conversely, products with a more limited substitution possibility, or with a more concentrated initial trade structure, display a weaker reallocation across suppliers.

The regional pattern also shows some differences. For most products, the largest increases are observed for suppliers such as Japan, East Asia, Southeast Asia, Oceania and Sub-Saharan Africa, while the response is generally weaker for intra-European sources and for some neighbouring regions. This suggests that, once the China–Europe flow is constrained, the model reallocates demand toward those regions that are closer substitutes in the Armington structure and that are better positioned in the benchmark trade pattern.

Finally, Figure 3 compares the results of SCN2 with those of SCN7, where the same import quota is imposed at 50% of the benchmark trade flow, but on a different source region. While SCN2 applies the quota to imports from China, SCN8 applies the same policy to imports from East Asia. The objective of this comparison is to verify whether the tariff required to eliminate out-of-quota trade changes when the targeted exporter changes, even if the quota rate is kept constant.

The results show that the differences between the two scenarios are relatively small, but not negligible. For flat, the tariff required in the East Asia scenario is slightly higher than in the China scenario, equal to 6.14% against 5.93%. A similar result is observed for pipes, where the tariff is 7.15% for East Asia and 7.10% for China. On the other hand, for long, rail and NFM_760200, the tariff is slightly higher when the quota is imposed on China.

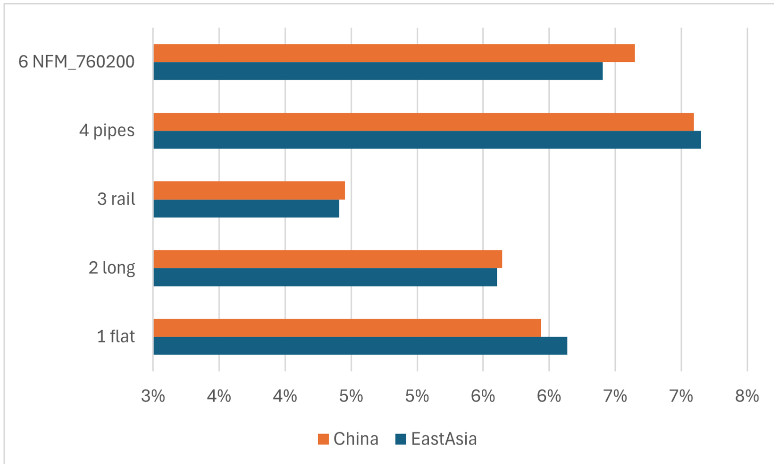

Figure 3: Different out-of-quota tariffs on EU imports from China and East Asia that eliminate out-of-quota trade

3.2 Scenarios SCN4–SCN6

The second group of scenarios is the mirror image of the previous one, with the difference that the quota is now imposed on Chinese exports toward the Southeast Asia aggregate, again for the same set of HS products k. The objective is therefore to identify the level of the export tax that eliminates out-of-quota trade under three different quota levels: 70% in SCN4, 50% in SCN5, and 30% in SCN6.

As in the previous exercise, the first result to highlight is the heterogeneity of the tax levels required to close out-of-quota trade. Figure 4 reports the values of TXS_Lk in SCN5, where the quota is set at 50% of the benchmark export flow. The results show that the effective export tax is not uniform across products. The highest value is again observed for pipes, where the tax required to eliminate out-of-quota trade reaches 11.57%. At the opposite end, the lowest value is no longer associated with rail, but with NFM_760200, for which the corresponding tax is equal to 6.68%. The remaining products lie between these two extremes: flat requires a tax of 9.45%, long 9.81%, and rail 8.31%.

This result is important for two reasons. First, it confirms, also on the export side, that a quota applied to a common product group does not translate into a uniform policy-equivalent tax. Even when the quantitative restriction is formally the same, the level of TXS_Lk needed to eliminate out-of-quota trade differs across HS components. Second, the ranking of products is not exactly the same as in the import-quota exercise. While pipes remains the product requiring the highest adjustment, the lowest value is now observed for NFM_760200. This suggests that the export-side response depends not only on the product-specific elasticities, but also on the trade structure relevant to the China–Southeast Asia flow.

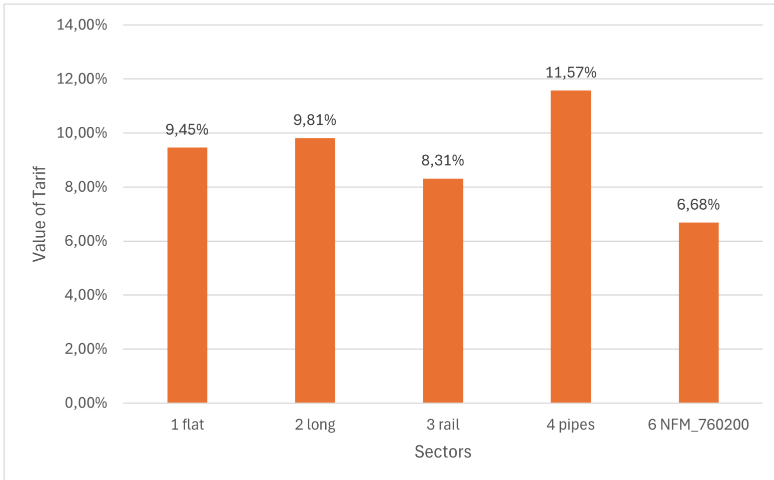

Figure 4: Level of tariff quota that eliminates exports out-of-quota in scenario SCN5

A more complete view of the tax levels required to eliminate out-of-quota trade is provided in Figure 5, which reports the results for all three export-quota scenarios. As expected, the tighter the quota becomes, the higher the export tax required to make the constraint fully binding. Moving from a quota equal to 70% of benchmark exports to 50% and then to 30%, TXS_Lk rises for all products. For flat, the effective export tax increases from 5.53% to 9.45% and then to 15.39%. For long, it rises from 5.50% to 9.81% and then to 16.06%. For rail, the corresponding values are 4.68%, 8.31%, and 13.45%. Pipes again shows the strongest response, with the tax increasing from 6.80% under the 70% quota to 11.57% under the 50% quota, and up to 18.88% when the quota is reduced to 30%. Finally, NFM_760200 remains the least affected component, moving from 3.35% to 6.68% and then to 12.06%.

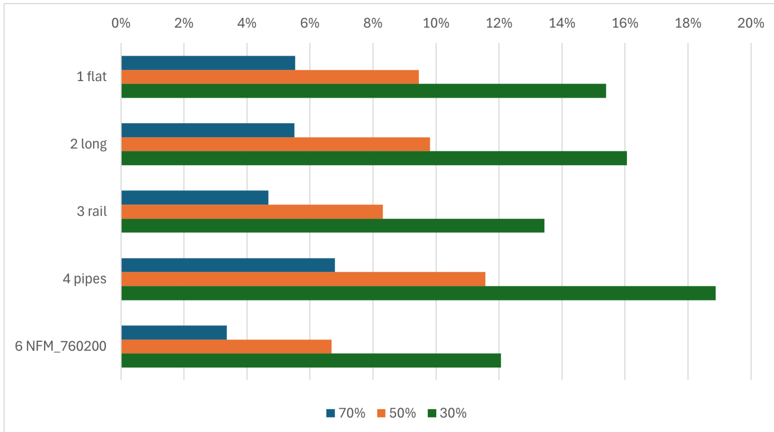

Figure 5: Level of tariff quota that eliminates exports out-of-quota in all scenarios

Overall, the export-side scenarios confirm the same general mechanism observed in the import package. A more restrictive quota requires a stronger tax adjustment, but the magnitude of this adjustment is not homogeneous across products. In this sense, the ETQ extension shows that the logic of the TRQ mechanism can be extended consistently to export restrictions, while preserving the possibility of capturing heterogeneity across HS components..

4 Conclusion

This paper has presented a new modelling framework that enriches the existing GTAP family of models by building a bridge between the GTAP-HS framework and the TRQ modelling literature. The contribution of the paper is twofold. First, it integrates an import-quota module into GTAP-HS, allowing TRQ regimes to be represented at the HS6 level. Second, it introduces a new export-quota module, designed to analyse policy instruments that restrict exports rather than imports.

Although the proposed export-quota module presents some limitations, it provides a useful tool for studying the growing use of export restrictions in strategic sectors, including critical raw materials, fertilizers, food products and other sensitive goods. In this sense, the model contributes to filling an important gap in applied trade policy analysis, where quota-based instruments are often represented only imperfectly or at an excessively aggregated level.

The simulation results are consistent with theoretical expectations and show that the model is able to capture the main mechanisms generated by quota constraints, including changes in trade flows, prices and quota rents. They also highlight the importance of using updated and product-specific trade elasticities, especially when the analysis is conducted at the HS6 level. Future developments may improve the current specification by refining the treatment of export quotas and by distinguishing more explicitly between import and export valuation concepts within the model structure.

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Appendix I: Regional and sectoral aggregation

Table 3: Regional aggregation

Aggregate region	GTAP countries included
Oceania	aus, nzl, xoc
China	chn
Japan	jpn
EastAsia	hkg, kor, mng, twn, xea, brn
SEAsia	khm, idn, lao, mys, phl, sgp, tha, vnm, xse
SouthAsia	afg, bgd, ind, npl, pak, lka, xsa
NAmerica	can, usa, xna
Mexico	mex
LatinAmer	arg, bol, bra, chl, col, ecu, pry, per, ury, ven, xsm, cri, gtm, hnd, nic, pan, slv, xca, dom, hti, jam, pri, tto, xcb
WestEurope	aut, bel, bgr, hrv, cyp, cze, dnk, est, fin, fra, deu, grc, hun, irl, ita, lva, ltu, lux, mlt, nld, pol, prt, rou, svk, svn, esp, swe, che, nor, xef
United Kingdom	gbr
RestofWorld	alb, srb, blr, rus, ukr, xee, xer, kaz, kgz, tjk, uzb, xsu, arm, aze, geo, xtw
MENA	bhr, irn, irq, isr, jor, kwt, lbn, omn, pse, qat, sau, syr, are, xws, dza, egy, mar, tun, xnf
Turkey	tur
SSA	ben, bfa, cmr, civ, gha, gin, mli, ner, nga, sen, tgo, xwf, caf, tcd, cog, cod, gnq, gab, xac, com, eth, ken, mdg, mwi, mus, moz, rwa, sdn, tza, uga, zmb, zwe, xec, bwa, swz, nam, zaf, xsc

Table 4: Sectoral aggregation

Aggregate sector	GTAP sector	Description
GrainsCrops	pdr	Paddy rice
	wht	Wheat
	gro	Cereal grains nec
	v_f	Vegetables, fruit, nuts
	osd	Oil seeds
	c_b	Sugar cane, sugar beet
	pfb	Plant-based fibers
	ocr	Crops nec
	pcr	Processed rice
MeatLstk	ctl	Bovine cattle, sheep and goats

Aggregate sector	GTAP sector	Description
	oap	Animal products nec
	rmk	Raw milk
	wol	Wool, silk-worm cocoons
	cmt	Bovine meat products
	omt	Meat products nec
	frs	Forestry
	fsh	Fishing
Extraction	coa	Coal
	oil	Oil
	gas	Gas
	oxt	Minerals nec
ProcFood	vol	Vegetable oils and fats
	mil	Dairy products
	sgr	Sugar
	ofd	Food products nec
	b_t	Beverages and tobacco products
TextWapp	tex	Textiles
	wap	Wearing apparel
LightMnfc	lea	Leather products
	lum	Wood products
	ppp	Paper products, publishing
	mvh	Motor vehicles and parts
	otn	Transport equipment nec
	omf	Manufactures nec
HeavyMnfc	p_c	Petroleum, coal products
	chm	Chemical products
	bph	Basic pharmaceutical products
	rpp	Rubber and plastic products
	nmm	Mineral products nec
	ele	Computer, electronic and optic
	eeq	Electrical equipment
	ome	Machinery and equipment nec
i_s	i_s	Ferrous metals
nfm	nfm	Metals nec
fmp	fmp	Metal products
Util_Cons	ely	Electricity
	gdt	Gas manufacture, distribution
	wtr	Water
	cns	Construction

Aggregate sector	GTAP sector	Description
TransComm	trd	Trade
	afs	Accommodation, Food and servic
	otp	Transport nec
	wtp	Water transport
	atp	Air transport
	whs	Warehousing and support activi
	cmn	Communication
OthServices	ofi	Financial services nec
	ins	Insurance
	rsa	Real estate activities
	obs	Business services nec
	ros	Recreational and other service
	osg	Public Administration and defe
	edu	Education
	hht	Human health and social work a
	dwe	Dwellings

Appendix II: Elasticities

Table 5: ESUBMK elasticities

Sector	Oceania	chn	jpn	EastAsia	SEAsia	SouthAsia	mex	NAmerica	LatinAmer	gbr	WestEurope	tur	MENA	SSA	RestofWorld
flat	12.18	12.18	12.18	12.18	12.18	12.18	12.18	12.18	12.18	12.18	12.18	12.18	12.18	12.18	12.18
long	12.77	12.77	12.77	12.77	12.77	12.77	12.77	12.77	12.77	12.77	12.77	12.77	12.77	12.77	12.77
rail	15.84	15.85	15.86	15.87	15.88	15.89	15.90	15.91	15.92	15.93	15.94	15.95	15.96	15.97	15.98
pipes	10.03	10.04	10.05	10.06	10.07	10.08	10.09	10.10	10.11	10.12	10.13	10.14	10.15	10.16	10.17
oth_is	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45
NFM_760	11.404	11.404	11.404	11.404	11.404	11.404	11.404	11.404	11.404	11.404	11.404	11.404	11.404	11.404	11.404
OTH_NFM	14.09	14.09	14.09	14.09	14.09	14.09	14.09	14.09	14.09	14.09	14.09	14.09	14.09	14.09	14.09

Table 6: ESUBDK elasticities

Sector	Oceania	chn	jpn	EastAsia	SEAsia	SouthAsia	mex	NAmerica	LatinAmer	gbr	WestEurope	tur	MENA	SSA	RestofWorld
flat	6.09	6.09	6.09	6.09	6.09	6.09	6.09	6.09	6.09	6.09	6.09	6.09	6.09	6.09	6.09
long	6.38	6.38	6.38	6.38	6.38	6.38	6.38	6.38	6.38	6.38	6.38	6.38	6.38	6.38	6.38
rail	7.92	7.93	7.94	7.95	7.96	7.97	7.98	7.99	7.100	7.101	7.102	7.103	7.104	7.105	7.106
pipes	5.01	5.02	5.03	5.04	5.05	5.06	5.07	5.08	5.09	5.10	5.11	5.12	5.13	5.14	5.15
oth_is	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25
NFM_760	5.70181	5.70181	5.70181	5.70181	5.70181	5.70181	5.70181	5.70181	5.70181	5.70181	5.70181	5.70181	5.70181	5.70181	5.70181
OTH_NFM	7.045	7.045	7.045	7.045	7.045	7.045	7.045	7.045	7.045	7.045	7.045	7.045	7.045	7.045	7.045

Table 7: ESUBD elasticities

Aggregate sector	Elasticity
GrainsCrops	2.8678
MeatLstk	3.3725
Extraction	6.0992
ProcFood	2.372
TextWapp	2.9675
fmp	2.61
LightMnfc	4.2267
nfm	7.045
i_s	2.225
HeavyMnfc	3.3538
Util_Cons	2.303
TransComm	1.6224
OthServices	1.51

Table 8: ESUBM elasticities

Aggregate sector	Elasticity
GrainsCrops	5.7356
MeatLstk	6.745
Extraction	12.1983
ProcFood	4.744
TextWapp	5.935
fmp	5.22
LightMnfc	8.4533
nfm	14.09
i_s	4.45
HeavyMnfc	6.7076
Util_Cons	4.606
TransComm	3.2448
OthServices	3.02