Incorporating heterogeneous export supply and import demand elasticities in a CGE model

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Introduction

Trade elasticities are key parameters determining the results of computable general equilibrium (CGE) experiments. Econometric methods to estimate trade elasticities range from reduced form approaches that use time-series variation in prices, to studies that identify demand elasticities from trade costs or by using instruments in cross-section or panel data, and finally to applications that separately identify supply and demand parameters in the absence of instruments (Hillberry and Hummels, 2013). Magnitudes of elasticities produced with different methods may vary by order of magnitude. Hillberry and Hummels (2013) advise using elasticities from econometric studies that employ identifying assumptions and utilize shocks that are similar in nature to those simulated with a CGE model.

In addition to choosing a set of trade elasticities to calibrate a CGE model, there are also critical decisions to be made regarding the structure of the model. Should the import demands be separable between import-import and import-domestic substitution? What about export supply elasticities? The typical Armington-based trade model, e.g. standard Global Trade Analysis Project (GTAP) model (Corong et al., 2017; Hertel, 1997), assumes that import-domestic substitution elasticities are smaller than import-import substitution elasticities. And export supply elasticities are effectively infinite, with no differentiation between goods destined for the domestic market vs. those goods that are exported.[1] However, there is recent evidence of export supply elasticities that are both finite and that vary by destination (Soderbery, 2018). This can have a dramatic impact on

[1] These are partial equilibrium elasticities determined by elasticity of transformation and destination-specific export revenue shares in the model. In the standard GTAP model the supply of goods to domestic and export markets is homogeneous, which is equivalent to very large elasticity of transformation.

the consequences of trade policy changes for national welfare, trade flows, production and employment.

The objectives of this work are to implement, in the context of a CGE model, advances in export supply and import demand elasticities estimation, examine the implications of heterogeneity for a CGE model mechanisms and outcomes, and conduct uncertainty and sensitivity analyses of CGE results with respect to trade elasticities and other model parameters. The analysis is based on the extension of the GTAP model, called GTAP-HS (Aguiar et al., 2021; Narayanan et al., 2010). GTAP-HS allows for the incorporation of detailed trade data and analysis of trade policies at the level of the Harmonized System's (HS) "tariff line". We estimate heterogeneous export supply and import demand elasticities for vegetables, fruits, and nuts (VFN) within GTAP data base "v_f" sector at the 6-digit HS level using Soderbery (2018) method. The GTAP-HS model is then modified to incorporate the heterogeneous export supply and calibrated to the estimated trade elasticities. We analyze ongoing trade frictions between the United States and its trading partners with a specific focus on VFN sectors. For this, we enhanced the GTAP database with production, trade, and domestic absorption of vegetables, fruits, and nuts sectors at the 6-digit HS level using production data from the Food and Agriculture Organization and trade flows from COMTRADE (see Chepeliev et al. (2021) for description of the GTAP-HS data base construction process).

The next section discusses in more details the trade elasticities, the model and the data base used. It is followed by the presentation of policy scenario and preliminary results. As it is a work in progress, we conclude the paper with discussion of the next steps.

Methodology

Trade elasticities

The Armington parameters currently available in the GTAP data base package were estimated in

Hertel et al. (2007) using cross-section data in Hummels (1999). Estimated more than a decade ago, these elasticities may not adequately reflect the structural changes that have affected the global agricultural production and food consumption landscape during the past two decades, nor do they leverage the wealth of time series data that has become available over the last decade. For instance, there are recent estimates of trade elasticities by Fontange et al. (2019) and Soderbery (2018). Fontagne et al. (2019) estimated trade elasticities at the product level (6-digit of the Harmonized System comprising 5,052 product categories) by exploiting the variation in bilateral applied tariffs for each product category for the universe of available country pairs. This is done by constructing a panel of bilateral applied tariffs and bilateral trade covering the period from 2001 to 2016.[2]

Soderbery (2018) developed a structural estimator of supply and demand that does not rely on instrumental variables and can identify variety by market specific heterogeneity in the elasticities. Using only readily available bilateral trade data, the method leverages price and quantity variation over time for the same good across export and import markets to identify heterogeneous elasticities (Soderbery, 2018). In this project, we applied Soderbery (2018) methodology to estimate importer-good specific elasticities of substitution within a composite imported good (Armington elasticities), and importer-exporter-good specific export supply elasticities at the 6-digit level of the Harmonized System. For the estimation we used COMTRADE price and quantity data from 2007 to 2018. The data contain 843 goods at the HS6-digit product codes, that include agriculture, seafood and lumber, and 220 importing and exporting countries. Even though not all of the 220 countries trade all 843 goods with one another, the number of elasticities to estimate was still very large. To reduce parameter space, following Soderbery (2018), it is assumed that small countries in the same region have identical supply technologies. As a result

[2] Using Fontagne et al. (2019) estimates, Chepeliev et al. (2021) parametrized substitution among goods imported from various source regions to analyze recent trade frictions between the United States and its trading partners.

of the restriction, 9 of the 22 designated regions in the econometric analysis are large individual countries, and remaining 13 are regional aggregates.

GTAP-HS model

The starting point in this modeling is a multi-sector, multi-region, comparative static GTAP-HS CGE model, which allows for the incorporation of detailed trade data and analysis of trade policies at the tariff line within CGE framework (Aguiar et al., 2021; Narayanan et al., 2010). The original concept behind the GTAP-HS modeling framework was developed in Grant et al. (2007). That study combined a fully disaggregated, subsector partial equilibrium model with a standard general equilibrium framework to analyze U.S. and international protection in dairy sectors. Inspired by Grant et al. (2007), Narayanan et al. (2010) modified the standard GTAP model (Hertel, 1997) by disaggregating automotive trade and applied it to the analysis of multilateral tariff liberalization for the Indian automotive industry. Aguiar et al. (2021) further generalized this approach for the GTAP v7 model (Corong et al., 2017).

In the GTAP-HS framework, the general idea is that sector or sectors of interest, VFN in our case, produce multiple commodities each of which faces differing degrees of competition in trade and trade policy. While the production sector definition follows the CGE model aggregation, the traded commodities are defined at the HS6 level. These commodities are consumed domestically and traded internationally. Demands for these goods by an aggregate domestic user are modeled in a two-stage process, with disaggregated commodities first substituting for one another at the tariff line level. They then enter the aggregate CGE model consumption category. To model international trade, the Armington assumption is employed in a way similar to the standard GTAP model (Corong et al., 2017; Hertel 1997): the disaggregated commodity (e.g. apples) that enters the aggregate GTAP consumption category VFN is a composite of a domestic good and an imported composite, where the imported composite consists of goods from various trading partners (Figure 1).

Estimated importer-good specific elasticities of substitution can be used directly as the GTAP-HS model is already equipped with the Armington specification of international trade in a way similar to the standard GTAP model: the disaggregated commodity (e.g. apples) that enters the aggregate GTAP consumption category "vegetables, fruit, nuts" is a composite of a domestic good and an imported composite, where the imported composite consists of goods from various trading partners. The estimates of importer-good specific elasticities of substitution serve as the constant elasticity of substitution (CES) parameters in the lower nest of import demand functions in the model, with the upper nest parameter set at half of the lower nest parameter.

To incorporate export supply elasticity estimates, we modify the GTAP-HS model by replacing the homogenous supply of domestically produced goods to domestic and export markets with a differentiated product specification. Many models of international trade employ nested constant elasticity of transformation (CET) functions to allocate domestic output between domestic and export markets (e.g., ENVISAGE (van der Mensbrugghe, 2019)). However, with the CET we will not be able to incorporate importer-exporter-good specific elasticities, as this functional form allows only exporter-good specific parameters. We develop a new approach and implement heterogeneous supply of output with an alternative two-level nested structure. In the top level, the domestic supply of each commodity is supplied to the domestic market and an aggregate export bundle using a CET function. The latter is allocated across regions of destination using constant ratio of elasticities of transformation, homothetic (CRETH) function (Dixon et al., 1976) in the second level (Figure 2). In contrast to CET, the CRETH function allows importer-exporter-good specific parameters. The parameters in the two-level structure are calibrated to the estimated export supply elasticities.

GTAP-HS data base

In this paper we use a special version of the GTAP-HS data base with focus on the vegetables, fruit and nuts (i.e., GTAP sector "v_f"). Output, domestic absorption and trade flows of this sector are disaggregated into 79 separate commodities within the standard GTAP data base (see Chepeliev et al. (2021) for description of the data base construction process). This version of the GTAP-HS data is based on GTAP 10A with Agricultural Production Targeting based on the Food and Agriculture Organization Data (Chepeliev, 2020), which, in turn, is a variant of the version 10 of the GTAP data base with reference year 2014 (Aguiar et al., 2019). The GTAP-HS data base is constructed at the GTAP disaggregated level to allow user specific aggregations across sectors and regions. In this analysis the data base is aggregated into 21 regions and 24 sectors (Appendix Tables A1 and A2), with vegetables, fruits and nuts sector disaggregated into 79 commodities.

Policy scenario

In March 2018, the United States implemented tariffs of 25% on steel and 10% on aluminum imports from most countries. These tariff increases induced retaliatory tariffs by trading partners. Few months later, in July 2018, the United States imposed sweeping tariffs on imports from China that started a tit-for-tat tariff war between the United States and China. These developments affected agricultural sectors in the United States and, in particular, vegetables, fruit and nuts. Retaliatory tariffs imposed on U.S. VFN sectors range from 5 percentage points imposed by Turkey to 100 percentage points imposed by India on walnuts. China applied higher tariffs across almost all vegetables, fruits and nuts disaggregated categories in the model, while other trading partners increased tariffs on few U.S. products (Figure 3). In our analysis, these tariff increases are implemented as shocks to the power of import tariffs imposed in the reference year of the analysis. The implemented shocks account for the existing tariff rates.

Preliminary results

The modified GTAP-HS model is applied to evaluate the impacts of retaliatory tariffs imposed on U.S. VFN sectors. We simulate this scenario with the original (homogenous supply of output) and modified GTAP-HS model.[3] The heterogeneous supply specification reduces the ease with which countries can reallocate their output to maximize their gains or minimize losses due to the shock. Preliminary results indicate that under heterogeneous specification the United States cannot seamlessly reallocate VFN exports from regions imposing import tariffs to other markets and these exports fall less, while U.S. VFN exporters see larger reductions in prices they receive.

Next steps

We explore how uncertainties in the trade elasticities contribute to the estimates of changes in trade, output, prices, and macro variables. It should be noted that with 79 vegetables, fruits, and nuts sectors and 21 regions in the model, number of parameters is very large. For this task, we will attempt to implement Monte-Carlo simulation with Latin Hypercube Sampling (McKoy et al., 1979) that may require fewer runs than systematic sensitivity analysis (SSA) via Gaussian Quadrature (DeVuyst and Preckel, 1997; Arndt and Pearson, 2000). We will also attempt to implement Morris method (Morris, 1991) that requires larger number of model runs. With this method, drivers and economic parameters are perturbed individually across their full distribution to elicit the impact of elementary effects of each model input, allowing identification and ranking of critical model variables (Hertel et al., 2016). This will determine relative importance of each uncertain model input, including trade elasticities and other parameters, for each model output.

[3] The preliminary analysis is conducted with nested constant elasticity of transformation (CET) functions to allocate domestic output between domestic and export markets, as in van der Mensbrugghe (2019).

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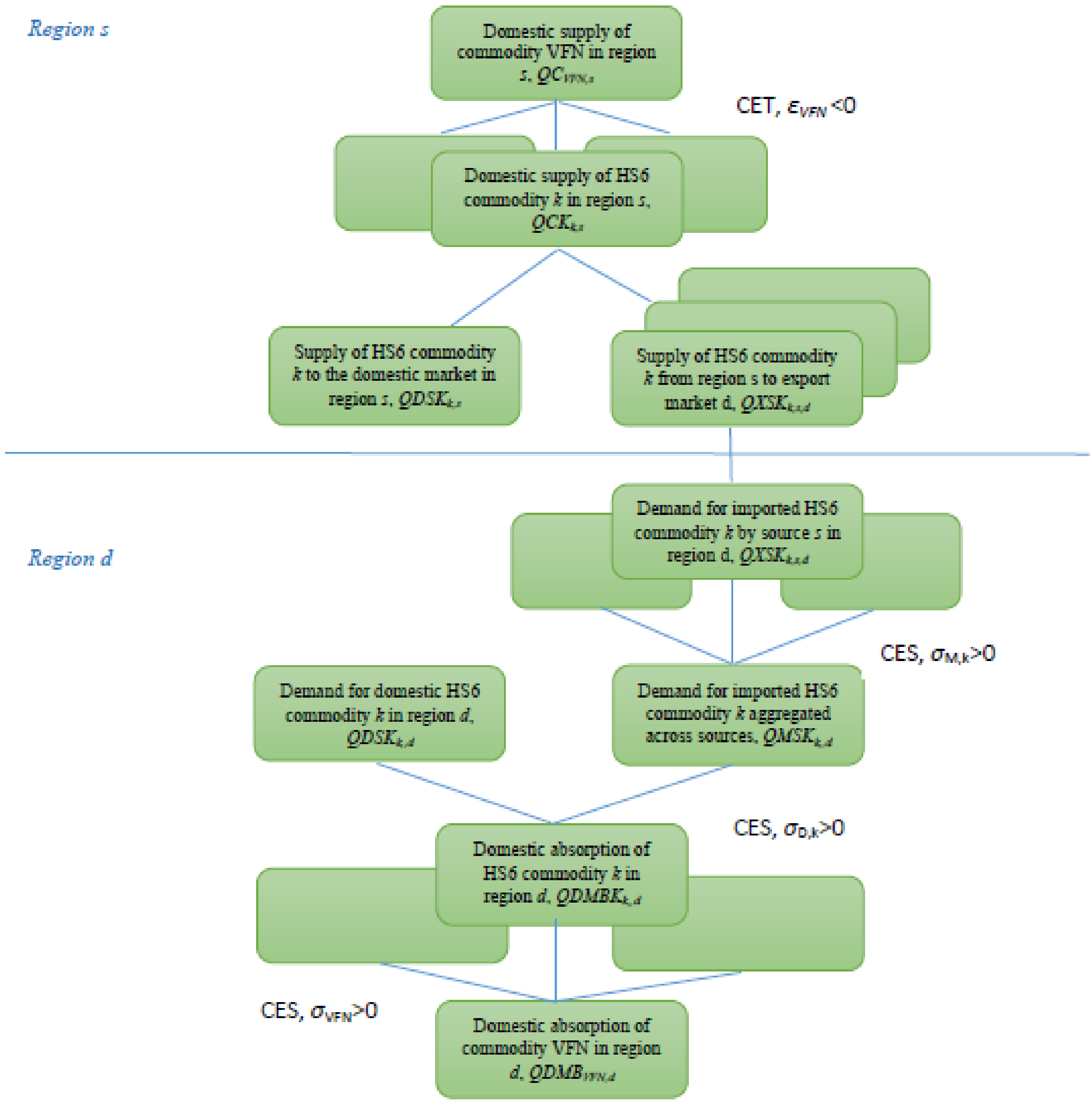

Figure 1 Quantity linkages in the GTAP-HS model
Source: Chepeliev et al. (2021)

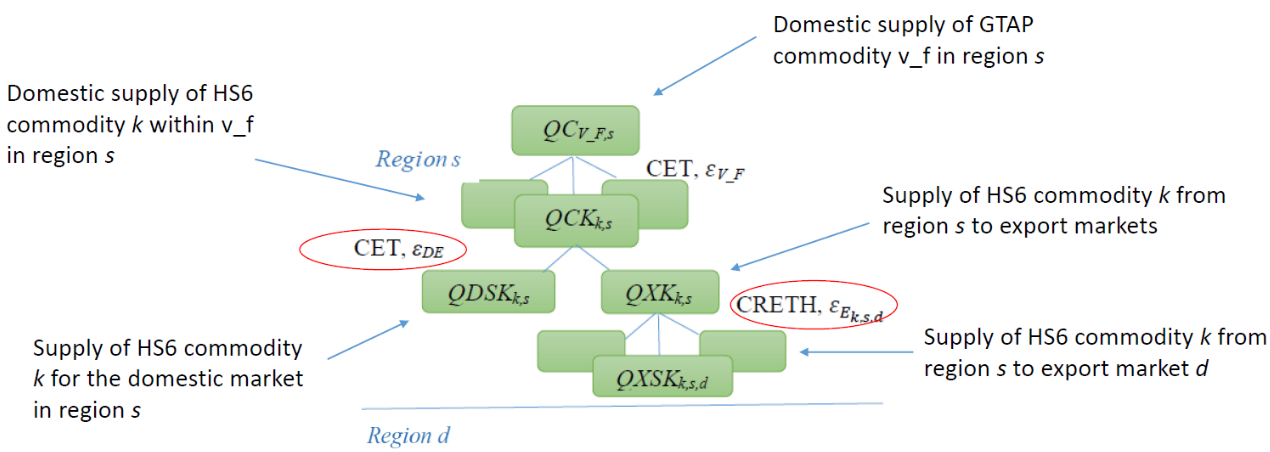

Figure 2 Quantity linkages in the GTAP-HS model with heterogenous output supply.
Source: Developed by authors.

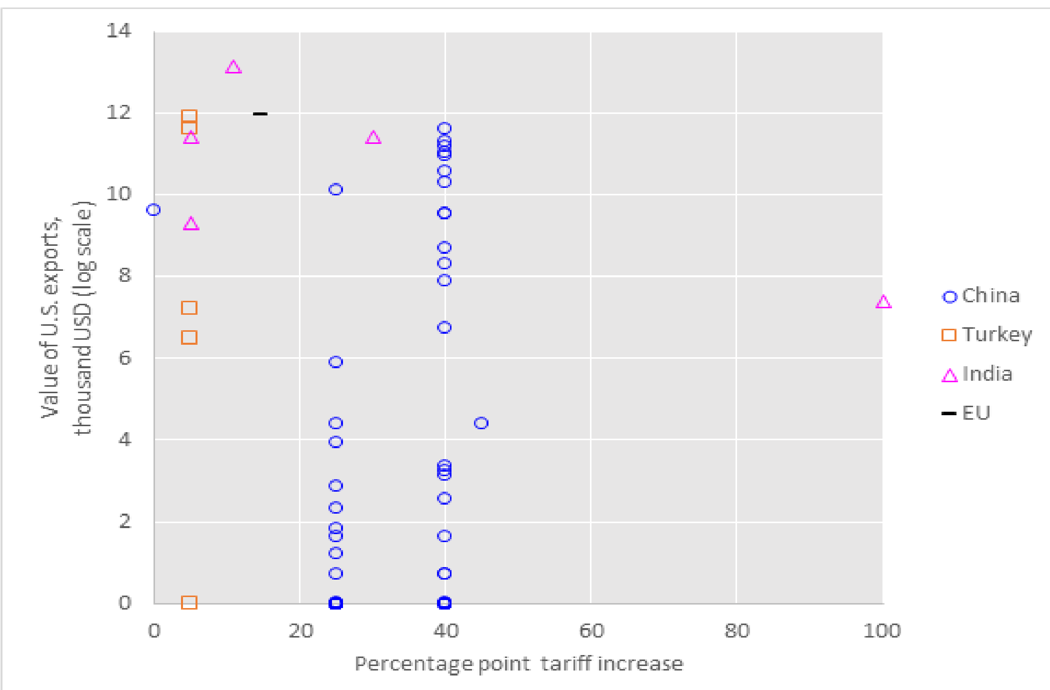

Figure 3 Export values vs. retaliatory tariffs imposed on U.S. vegetables, fruits and nuts (2014 trade values).

Source: Chepeliev et al. (2021)

Appendix A

Table A1 Aggregation of the GTAP regions

No.	Aggregate region	Description	GTAP region
1	Oceania	Oceania	aus nzl xoc
2	China	China	chn
3	Japan	Japan	jpn
4	AgImp	Agricultural Importers	kor twn sgp che irn sau are egy
5	Asia	Asia	mng xea brn khm lao phl xse bgd npl pak lka xsa hkg
6	Indonesia	Indonesia	idn
7	Turkey	Turkey	tur
8	AgExp	Other Agricultural Exporters	mys tha vnm chl ukr zaf
9	India	India	ind
10	Canada	Canada	can
11	USA	USA	usa
12	Mexico	Mexico	mex
13	SouAm	South America	xna bol col ecu pry per ury ven xsm cri gtm hnd nic pan slv xca dom jam pri tto xcb
14	Argentina	Argentina	arg
15	Brazil	Brazil	bra
16	EU	European Union	aut bel cyp cze dnk est fin fra deu grc hun irl ita lva ltu lux mlt nld pol prt svk svn esp swe gbr bgr hrv rou
17	Europe	Europe	nor xef alb blr xee xer kaz kgz tjk xsu arm aze geo
18	Russia	Russia	rus
19	MENA	Middle East and North Africa	bhr isr jor kwt omn qat xws mar tun xnf
20	ECOWAS	Economic Community of West African States	ben bfa civ gha gin nga sen tgo xwf
21	Africa	Africa	cmr xcf xac eth ken mdg mwi mus moz rwa tza uga zmb zwe xec bwa nam xsc xtw

Source: Chepeliev et al. (2021)

Table A2 Aggregation of the GTAP sectors

	Aggregated sectors		Disaggregated sectors
	Code	**Description**	
1	Rice	Paddy rice	pdr pcr
2	Wheat	Wheat	wht
3	CoarseGr	Coarse grains	gro
4	VFN	Vegetables, fruit, nuts	v_f
5	Oilseeds	Oilseeds	osd
6	Sugar	Sugar cane, sugar beet	c_b sgr
7	PlantFibers	Plant-based fibers	pfb
8	OtherCrops	Other crops	ocr
9	Animals	Livestock and Meat Products	ctl oap wol
10	RMK	Raw milk	rmk
11	NatResources	Natural resources	frs fsh oxt
12	Coal	Coal	coa
13	Oil	Oil	oil
14	Gas	Gas	gas gdt
15	Meat	Bovine and other meat products	cmt omt
16	VegOil	Vegetable oils and fats	vol
17	Dairy	Dairy products	mil
18	OFD	Food products nec	ofd
19	B_t	Beverages and tobacco products	b_t
20	L_Mfg	Light Manufacturing	tex wap lea lum ppp fmp ele mvh otn omf
21	P_c	Petroleum, coal products	p_c
22	H_Mfg	Heavy Manufacturing	chm bph rpp nmm i_s nfm eeq ome
23	ELY	Electricity	ely
24	OthServ	Other services	wtr cns trd afs otp wtp atp whs cmn ofi ins rsa obs ros osg edu hht dwe

Source: Developed by authors.