Product-Level Trade Elasticities*

Lionel Fontagné (Paris School of Economics – Université Paris I and CEPII)†

Houssein Guimbard (CEPII)‡ Gianluca Orefice (CEPII)§

Draft: June 14, 2019

Abstract

We estimate trade elasticities at the product level (6-digit of the Harmonized System comprising more than 5,000 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 2001 to 2016. We address potential endogeneity issues as well as heteroskedasticity and selection bias due to zero flows. The obtained elasticities are centered around -6. We finally highlight the differences in the gains from trade arising from considering heterogeneous rather than average trade elasticities. All product level elasticities are made publicly available for sake of scrutiny and use by other researchers.

Key Words: Elasticity, International Trade.

JEL Codes: F14, F17.

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†Centre d'Economie de la Sorbonne, 106-112 Bd de l'Hôpital, F-75647 Paris Cedex 13. Email: lionel.fontagne@univ-paris1.fr.

‡CEPII, 20 avenue de Ségur 75007 Paris. Email: houssein.guimbard@cepii.fr.

§CEPII, 20 avenue de Ségur 75007 Paris. Email: gianluca.orefice@cepii.fr.

Introduction

Trade elasticity is an important parameter in international trade models, especially when it comes to provide an order of magnitude of the welfare impacts of trade liberalization, or conversely the cost of returning to autarky: the welfare gain from trade is a function of the change in the share of domestic expenditure and the trade elasticity to variable trade costs (Arkolakis, Costinot & Rodriguez-Clare 2012). If one assumes that a tariff is mostly a variable trade cost imposed by the importer country, then the elasticity of trade values to changes in tariffs becomes the key parameter for many scholars and practitioners aiming at evaluating the welfare effect of changes in trade policy – see the approach coined as trade theory "with numbers" popularized by Costinot & Rodriguez-Clare (2014).[1] A relatively closed economy (typically a large country), or a country in which imports have close domestic substitutes, will suffer little pain from moving to autarky as trade-induced welfare gains are small (Costinot & Rodriguez-Clare 2018). But while the first statistic – how much does a country trade with itself as a proportion of its total expenditures – is directly observable, available estimates of the trade elasticity diverge considerably. In their survey of issues related to the analysis of commercial policies, Goldberg & Pavcnik (2016) stress that "*perhaps surprisingly, estimates of the trade elasticity based on* actual *trade policy changes are scarce [...] it is surprising that trade policy has not been exploited to a larger extent to identify this crucial parameter*".[2] This paper aims at filling at least partially this gap. By systematically scanning applied protection and import flows at the bilateral and product level for a full matrix of bilateral trade, we provide a set of estimations of theory-consistent trade elasticities at product level. So doing we will have a comprehensive view of trade policies, including for countries having hardly liberalized their trade, and that are generally absent from existing studies.[3]

Trade elasticity can be estimated at different levels of disaggregation ranging from the sector to the product or even the variety. In the latter case, it has to be estimated at the level of individual exporters using transaction-level custom data,[4] with the challenge that export prices and export quantities are endogenous at the firm level.[5] To overcome this difficulty, and also because firm level exports are hardly available for multiple countries,[6] we rely here on the finest grain – the HS 6-digit product level – when firm-level data is not available. So doing, we implicitly aggregate firms (at different levels of productivity) within a given exporting country-product cell; in this case the shape of the distribution of productivity will indeed impact the observed elasticity (Chaney

[1] We consider in what follows that the current tariffs is applied at the date of the trade flow. They may differ from future tariffs to the extent that tariffs are consolidated above the applied or even not consolidated. Tariffs of advanced countries are fully consolidated however.

[2] See Goldberg & Pavcnik (2016) pp. 24-25. One exception is Amiti, Redding & Weinstein (2019) who take advantage of the big swings in US tariffs and rely on US imports from January 2017 to December 2018 at the origin-month-HS10 level: they estimate an elasticity of substitution between varieties equal to 6. See column 3 of Table 1 accounting for zero flows.

[3] Simonovska & Waugh (2014a) stress that trade elasticity estimates relying on advanced countries' tariffs only, due to data limitation, may not be accurate to evaluate welfare changes for developing countries.

[4] A variety is then defined as a specific product produced by a specific firm.

[5] Fontagné, Martin & Orefice (2018) use a firm level time varying instrumental variable for export prices and estimate firm-level elasticity to tariff controlling for how exporters absorb tariff shock in their export price.

[6] Bas, Mayer & Thoenig (2017) is an exception, as they managed to combine French and Chinese firm level exports to estimate trade elasticities.

2008).[7] Sector level trade elasticities are (downward) biased if the elasticity varies a lot across products and/or due to the covariance between the dispersion of tariffs across countries and the sectoral trade elasticities (Imbs & Mejean 2015). This bias is reduced here as we rely on a very disaggregated product classification.

Trade elasticity can have different interpretations based on the underlying theoretical framework and on the level of aggregation. Feenstra, Luck, Obstfeld & Russ (2014) make a distinction between the "macro" Armington elasticity between domestic and imported goods, and the "micro" elasticity of substitution between different import suppliers.[8] Indeed, the two elasticities are usually nested in a (e.g. CES) preference structure.[9] In line with this distinction we compute here "micro" trade elasticities as we test how bilateral tariffs affect bilateral import flows.

Trade elasticity can be estimated with a demand system (Feenstra 1994, Broda & Weinstein 2006), using the non-arbitrage condition and product level price data (Simonovska & Waugh 2014a, Giri, Yi & Yilmazkuday 2018), considering imports as inputs in the GDP function (Kee, Nicita & Olarreaga 2008), or based on a gravity framework (Caliendo & Parro 2015). While Caliendo & Parro (2015) rely on the multiplicative properties of the gravity equation in order to cancel out unobserved trade costs, in line with the "ratio approach" introduced by Head & Ries (2001) or Head & Mayer (2002) and systematized as "Tetrads" by Martin, Mayer & Thoenig (2008) and Head, Mayer & Ries (2010), we rely here on a gravity framework using a strategy of fixed effects as suggested by Head & Mayer (2014).

The choice of an identification strategy consequently differs in terms of observed trade costs. Estimating a demand system will resort to volume and prices at the finest level of the classification of traded products (Feenstra 1994) with no *explicit* consideration of the trade policy. The latter is assumed to be fully passed into the prices at the border. Similarly, in Simonovska & Waugh (2014a) and Giri et al. (2018), the maximum price difference between countries for detailed price level data for the year 2004 is a proxy of trade frictions.[10] Unit values are used as proxy of prices in Kee et al. (2008), when estimating the import demand elasticity as the percentage change in the imported quantity holding prices of other goods, productivity and endowment of the importer constant. In contrast, Caliendo & Parro (2015) rely on the cross-sectional variations in trade shares and applied tariffs for 20 sectors and 31 countries to estimate sectoral trade elasticities.

In this paper we aim at covering the largest number of importing countries and the finest degree of product disaggregation in our estimations, hence our choice of relying on actual trade policies. To proceed, we use the

[7] Starting from firm level export data for the universe of French manufacturing firms, Fontagné & Orefice (2018) conduct estimations of trade elasticities at the sector level and show that the effect of stringent Non-Tariff Measures in reducing export flows is magnified in more homogeneous sectors, as predicted by theory.

[8] In a seminal paper, Armington (1969) introduced a preference model whereby goods were differentiated by their origin – domestic *versus* imported.

[9] See e.g. Hertel, Hummels, Ivanic & Keeney (2007) who obtain elasticities of substitution between goods of different origins, at the sector level, ranging from 1.8 to 12.9 (excluding gas, the usual outlier).

[10] Simonovska & Waugh (2014a) use disaggregated prices from the International Comparison Programme for 62 product categories matched with trade data in a cross section of 123 countries. Giri et al. (2018) adopt the same strategy for 12 EU countries and 1410 goods (in 19 traded sectors) in 1990.

most disaggregated level of information on trade policies and imports available for the universe of products and importing countries,[11] which is the 6-digit Harmonized System (HS6 thereafter) comprising more than 5,000 different product categories for a sample of 152 importing countries. A typical product category here will be "Trousers, bib and brace overalls, breeches and shorts; men's or boys', of textile materials (other than wool or fine animal hair, cotton or synthetic fibres), knitted or crocheted". Since we use bilateral trade data at the product category level, we do not observe the differentiation of products among firms of a given exporting country. However, given the very disaggregated product category, this concern is very reduced here. We compute the tariff elasticity comparing sales of e.g. Indian and Chinese trousers and shorts on importing markets, controlling with destination fixed effects for any systematic difference in elasticities among importers.[12] For each HS6 product category we observe the universe of bilateral trade flows between countries, in value, in a given year, and the tariff (preferential or not) applied by each importer to the exporter for this product. This information is available for the years 2001, 2004, 2007, 2010, 2013 and 2016.[13] Most of the variation in tariffs is cross-sectional, we therefore exploit the panel nature of this dataset, and explain - for a given importer - the cross-country variation in imports with the cross-country variation in tariff.

We show that, when estimated at the HS6 product-category level for the universe of products and country-pairs, the distribution of tariff elasticity is centered around -6. There is large variation around this value, and our results will be useful for a wide set of exercises exploiting the product level dimension of this elasticity.[14] This result compares with elasticities presented in the trade literature: Romalis (2007) obtains elasticities of substitution between 6.2 and 10.9 at the HS6 level, while Broda & Weinstein (2006) obtain for US imports an average value of 6.6 with 2,715 SITC 5-digit categories, and 12.6 at the tariff line (13,972 categories) level for the period 1990-2001.[15] Using HS6 import data and unit values for 117 importers over the period 1988-2001 Kee et al. (2008) obtain a simple average import demand elasticity of -3.12. Using a simulated method of moments and international differences in individual price data Simonovska & Waugh (2014a) present a benchmark trade elasticity of 4.12 and Giri et al. (2018) a median trade elasticity of 4.38 (minimum 2.97, maximum 8.94). At the industry level, Ossa (2014) estimates CES elasticities of substitution by pooling the main world importers in cross section and obtain a mean value of 3.42 (ranging from 1.91 for Other animal products to 10.07 for Wheat). Other calibration exercises however point to larger elasticities: Hillberry, Anderson, Balistreri & Fox

[11] Indeed, imports can be observed at the tariff line for single countries. This is why US imports have repeatedly been used to estimate trade elasticities. An influential set of elasticities at the tariff line level for the US (13,972 product categories) and the 1990-2001 period is Broda & Weinstein (2006).

[12] Broda, Greenfield & Weinstein (2006) examine whether substitution elasticities vary systematically in relation with the income per capita of the importer and find no such evidence notwithstanding idiosyncratic differences across countries. In contrast they obtain large differences in elasticities among goods: the mean elasticity of substitution is much higher for commodities than for reference priced or differentiated products, using Rauch's classification.

[13] As discussed in Anderson & Yotov (2016), panel estimations with non-consecutive years are preferred to estimations using panel data pooled over consecutive years. The use of non-consecutive years allows for the adjustment of the dependent variable in presence of trade policy change (i.e. tariff change in our case).

[14] The estimated elasticities are made publicly available at `http://www.cepii.fr/CEPII/en/bdd_modele/presentation.asp?id=35`

[15] Notice that the median is much lower, respectively 2.7 and 3.1.

(2005) show that reproducing variations in bilateral trade shares with a standard computable general equilibrium model imposes elasticities of substitution larger that 15 in half of the sectors.[16] Even restricting the comparison to the estimates relying on gravity leads to a wide range of values, as shown by the recollection of 744 elasticities present in 32 papers (Head & Mayer 2014). In their full sample the median trade elasticity is 3.19, with a large standard deviation (8.93). Restricting the comparison to gravity estimates controlling for multilateral resistance terms and exploiting the variation in tariffs or freight rates (435 elasticities), Head & Mayer (2014) obtain a median of 5.03 which is their preferred value (still the standard deviation is 9.3).

Gains from trade with heterogenous tariff elasticity across HS6 product categories raise specific issues that we explore in the second part of the paper. Namely, we compare welfare gains from trade using *heterogeneous* vs *average* (homogeneous) trade elasticities. This is of crucial interest for both scholars and policy makers aiming at evaluating the welfare impact of trade policies, and represents the second contribution of our paper.[17]

The rest of the paper is structured as follows. We present data and our empirical strategy in Section 1. Our results on the estimate of the trade elasticities at the product level are given in section 2. In section 3 we perform a standard calculation following Arkolakis et al. (2012) and compare the change in welfare from moving to autarky obtained using heterogeneous elasticity *versus* adopting an average (product invariant) elasticity. The last section concludes.

1 Data and empirical strategy

We use two datasets: (i) $BACI$ database on worldwide exports, (ii) $MAcMap-HS6$ database on applied bilateral tariffs for the years 2001, 2004, 2007, 2010, 2013 and 2016. Gravity control variables introduced in the estimations (such as distance and common colony) come from CEPII gravity database.

1.1 FOB imports in BACI

For a full matrix of importer and exporter countries, we use the BACI database: it provides information on bilateral trade flows, in current US Dollars, over the period 1996-2016 at the HS6 level.[18]

Based on COMTRADE, BACI has three specific features useful for our exercise. First, BACI is filling empty cells in the world trade matrix using mirror trade flows. Second, BACI is reconciling reported values between exporter i and importer j for a given product category k and year t pair: one can indifferently use $X_{i,j,k,t}$

[16] More precisely, in a calibration-as-estimation procedure applied to the GTAP model, this elasticity had to be set at a value above 15 in 21 out of 41 sectors in order to reproduce the actual variation in trade shares. Authors failed to report solution in five sectors.

[17] A related question – the heterogeneity in tariff elasticity across countries and levels of trade costs – has been recently explored by Brooks & Pujolas (forthcoming). Authors show that trade is more inelastic when the country approaches to autarky. In this case, marginal increases in the import penetration for countries close to autarky imply larger welfare effects than for countries close to the observed trade.

[18] See (Gaulier & Zignago 2010) concerning the documentation of this database of from CEPII.

or $M_{j,i,k,t}$ which are identical.[19] Third, BACI is providing import values net of transport costs (hence FOB): transport and insurance rates were estimated regressing the observed CIF/FOB ratio for a given flow on gravity variables and a product-specific world median unit value.[20]

1.2 MAcMap-HS6 tariffs

To estimate the elasticity of import values to tariffs we need information on bilateral applied tariffs for all exporters and importers and all products. This information is provided by MAcMap-HS6.[21] For each product and each country pair, MAcMap-HS6 provides the preferential applied tariff inclusive of *advalorem* equivalents of tariff quotas and specific tariffs. The tariff data is available for the years 2001, 2004, 2007, 2010, 2013 and 2016. The methodology is common to the different waves of data. Interestingly, in order to minimize endogeneity problems when computing unit values or when aggregating data, MAcMap-HS6 relies on the method coined as "reference groups" whereby bilateral trade or unit values are replaced by those of a group of similar countries.[22] An important feature of the database is that it takes into account specific duties (transformed in ad-valorem ones) as well as Tariff Rate Quotas.[23] Contingent protection is not included.

1.3 Combining the two databases

MAcMap-HS6 covers 159 importers for the year 2001. Subsequent releases have increased coverage with the exception of year 2010 for which we have only 152 importers. We therefore keep the sample of 152 importers present in all the releases of MAcMap-HS6. On the exporting side the constraint is less binding and we keep exporters present in BACI since 2001. Ultimately, we have 189 exporters to 152 destinations in each year. At the HS6 level, the worldwide full balanced matrix of bilateral trade comprises a lot of zeros. However, not all these zeros convey useful information for our exercise. If country j does not import product k from exporter i, this might just be due to the fact that i never exports k. In this case, including all the zeros originating from country i in product k across all destinations j would inflate the dataset with useless information. We therefore do a fill-in of the world trade matrix only when country i is exporting product k to at least one destination over the period. We then match all the non-zero and zero trade flows with the tariffs $\tau_{i,j,k,t}$. After merging these two datasets, for each of the 5,052 HS 6-digit product categories, we end up with a panel dataset of country pairs for the years 2001, 2004, 2007, 2010, 2013 and 2016. The non-consecutive nature of our dataset allows

[19] The reliability of reporting countries is used as weight to reconcile bilateral trade flows.

[20] BACI is freely available online to users of COMTRADE database. See `http://www.cepii.fr/CEPII/fr/bdd_modele/presentation.asp?id=1`.

[21] This version of MAcMap is devoted to analytical purposes (Guimbard, Jean, Mimouni & Pichot 2012). This HS6 information is an aggregation of tariff line level instruments performed by the International Trade Center (ITC, UNCTAD-WTO) and made available to the CEPII.

[22] Reference groups in MAcMap are built following clustering procedures on GDP per capita and trade openness. This methodology produces large groups of countries sharing similar trade-related characteristics. See (Bouët, Decreux, Fontagné, Jean & Laborde 2008) for further details on the foundations of the reference group method.

[23] Filling rates are used to choose between the inside and outside tariff.

our dependent variable to adjust in presence of trade policy change i.e. tariff change in our case, (Anderson & Yotov 2016).

Let's now depict world protection adopting this systematic approach of bilateral trade flows and tariffs. In table 1 we report the share of each type of tariff in force over the total non-missing importer-exporter-HS6 combinations. The first observation is that the vast majority of non-zero tariffs are ad valorem. Specific tariffs or compound tariffs (combining *advalorem* and specific elements on the same tariff line) sum up to around one percent of all non-missing importer-exporter-HS6 observations. However, given the potentially high protection they provide, specific or compound tariffs should not be disregarded. We will keep track of the *advalorem* equivalent of these specific or compound tariffs in our calculations. The second observation is that the 2000's correspond to a steady phasing out of tariffs: the share of tariff lines equal to zero doubled between 2001 and 2004 (from 18% to 31%), up to representing the 40% of non-missing occurrences in 2016. This "zeroing" goes beyond the commitments of the Uruguay Round and mirrors either the phasing out of nuisance tariffs or the phasing-in of new Regional Trade Agreements (RTAs).[24] These two observations call for a deeper analysis on: i) the coverage of trade by non-MFN tariffs and ii) the respective contributions of the within and between changes in products' bilateral tariffs.

Table 1: Share of the different tariff types for non-missing importer-exporter-HS6 cells

Year	% of cells with tariff:			
	Per unit	Ad-valorem	Zero applied	Compound
2001	0.4	79.7	18.7	1.2
2004	0.7	68.0	31.0	0.3
2007	0.7	63.4	35.6	0.3
2010	0.5	61.5	37.7	0.3
2013	0.5	59.8	39.4	0.3
2016	0.6	59.0	40.0	0.4

Note: this table reports the share of per unit, ad-valorem, compound and zero tariffs in force for non-missing importer-exporter-HS6 combinations.
Source: MAcMap-HS6, authors calculation.

We now turn to the use of MFN *versus* preferential tariff rates by importers. In table 2 we report the share of non-missing importer-exporter-HS6 combinations adopting MFN *versus* preferential tariffs. The entry into force of new RTAs over the last decades, discussed in detail in Freund & Ornelas (2010), translates into a reduction in the frequency of MFN tariffs as shown in table 2. Notwithstanding this slight decline, MFN tariffs remain extraordinary present in world trade, representing three bilateral tariffs out of four on average.

In order to guide our empirical exercise, it is crucial to characterize the sources of variation of tariffs in our data base. Product level tariffs can vary both within each country pair over time (*within* variation) and/or

[24]Nuisance tariffs are duties close to zero percent not worth collecting at the border.

Table 2: Share of non-missing importer-exporter-HS6 cells with Preferential vs MFN tariff.

Year	% of cells with:	
	Preferential tariff	MFN tariff
2001	22.2	77.8
2004	20.2	79.8
2007	21.7	78.3
2010	23.5	76.5
2013	25.6	74.4
2016	25.6	74.4

Note: this table reports the share of non-missing importer-exporter-HS6 combinations with respectively preferential and MFN tariff in force.
Source: MAcMap-HS6, authors calculation.

across trade partners within a given year (*between* variation).[25] In table 3 we report the mean variance, between and within country-pairs, for each HS section. Most of the variance takes place between country pairs for each product; we therefore exploit the *between* pairs variation in bilateral tariffs to estimate trade elasticities in the next section. The contribution of the within variance is not negligible for section XI (corresponding to the phasing out of protection for Textiles and Textile articles). The largest between variation is observed for section IV corresponding to Prepared Foodstuffs, Beverages and Spirits. The latter sector is also the one exhibiting the highest average protection among all country pairs (16.9 percent in 2016) and the highest variance as well (38.6) as shown in tables A1 and A2 in the Appendix.

[25]The within variation therefore reflects the variability of tariffs over time; while the between variation reflects the heterogeneity of tariffs imposed by different countries in a given year.

Table 3: Within *vs* between variation in product level bilateral applied tariffs, by HS section, 2001-2016.

		Variance	
		Within	*Between*
I	Live Animals and Animal Products	0.112	0.217
II	Vegetable Products	0.104	0.194
III	Animal or vegetable fats and oils	0.074	0.136
IV	Prepared foodstuffs, beverages and tobacco	0.159	0.259
V	Mineral products	0.033	0.060
VI	Products of chemical industries	0.038	0.061
VII	Plastic and articles thereof	0.043	0.079
VIII	Raw hides and skins, leather and article thereof	0.051	0.104
IX	Wood/Cork and articles of Wood/Cork;	0.063	0.101
X	Pulp of wood or other cellulosic materials	0.040	0.075
XI	Textile and textile articles	0.100	0.116
XII	Footwear, Headgear, Umbrellas and prepared feathers	0.070	0.126
XIII	Articles of stone, plaster, ceramic and glass	0.045	0.100
XIV	Natural cultured pearls and precious stones and metals	0.050	0.109
XV	Base metals and articles of base metals	0.038	0.075
XVI	Machinery and mechanical appliances and electrical machinery	0.037	0.067
XVII	Vehicles, Aircraft and transport equipment	0.050	0.092
XVIII	Optical, photographic, precision and medical instruments	0.042	0.079
XIX	Arms and ammunitions	0.104	0.209
XX	Miscellaneous	0.053	0.108
XXI	Works of art	0.047	0.106

Note: To build this table we computed the *within* and *between* variance for each HS 6-digit product. HS 6-digit variances have been then aggregated at the level of HS section by simple average.

1.4 Empirical strategy

To estimate the tariff elasticity for each of the 5,052 HS6 product categories, we rely on a standard structural gravity framework accounting for multilateral resistance terms by using country-time fixed effects. The following empirical model is then performed to recover the tariff elasticity ε at the product level (hence 5,052 times):

$$ln(Import_{j,i,t}) = \theta_{it} + \theta_{jt} + \varepsilon ln\left(1 + \tau_{j,i,t}\right) + \beta_1 ln\left(Distance_{i,j}\right) + \beta_2\left(Colony_{i,j}\right) + \beta_3\left(Contiguity_{i,j}\right) + \epsilon_{i,j,t} \quad (1)$$

where $\varepsilon = (1 - \sigma)$, σ being the elasticity of substitution between varieties of HS6 products exported by different countries in the usual CES framework. Equation (1) is performed for each HS 6-digit category of product k. The final database contains a variable indicating the tariff elasticity ε for each HS6 position.

To address the heteroskedasticity in the error term (and the zero trade flows problem - missing information), we follow Santos-Silva & Tenreyro (2006) and adopt a PPML estimator as baseline (and preferred) estimator to run Equation (1). The distribution of tariff elasticity obtained using a PPML estimator is shown in Figure 1. The comparison between the distribution of estimated elasticities obtained by PPML (Figure 1) and OLS (Figure A1) illustrates the bias emerging in disregarding the zero trade flow problem with OLS - see section 2.2 for detailed discussion on baseline results. In Equation 1 we always include exporter-year (θ_{it}) and importer-year (θ_{jt}) fixed effects to fully control for exporter and importer multilateral resistance terms.[26] By doing so, and running Equation (1) by product category, we exploit the variation in tariffs imposed in different destinations on a given exporter at different points in time.[27] Finally, to control for bilateral specific geographic related trade costs (as derived by a standard gravity model for trade), we always include distance (in logarithm), a dummy for common colony, and a dummy for common border.[28]

Beyond the usual third-country effects extensively addressed in the recent literature on structural gravity, a proper identification of the bilateral tariff elasticity should control for the reaction of third countries $n = 1...N$ (with $n \neq j$) to changes in bilateral tariff τ_{ijt}. Indeed, if a third country $n \neq j$ reacts to a change in the τ_{ij} tariff (e.g. to avoid trade diversion), the change in bilateral trade ij is the results of two channels: (i) the direct effect of the variation in the bilateral tariff τ_{ijt} and, (ii) the indirect effect through the modified relative market access with respect to third country n. Our exporter-year fixed effects θ_{it} also capture the *average* tariff imposed by third countries $n \neq j$ to the exporter country i (i.e. tariff faced by exporter country i, at time t, in exporting

[26]See Head & Mayer (2014) for a complete discussion on how to control for multilateral resistance terms. Note that relying on a strategy of country (or country-time) fixed effects estimated with a PPML is consistent because the sum of fitted export values for each exporter (importer) is equal to its actual output (expenditure) (Fally 2015). This property of the PPML, has been extensively exploited by Anderson, Larch & Yotov (2018) to simulate in full endowment general equilibrium the impact of changes in the trade cost matrix.

[27]Remember the panel nature of our tariff data available for years 2001, 2004, 2007, 2010, 2013, 2016.

[28]While technically possible, we could not include country-pair fixed effects because of the short time horizon in our panel and the small within variation in tariff.

to third countries n).[29]

Considered the inclusion of country-year fixed effects controlling for any unobserved country-year specific factors, and the geographic controls capturing the bilateral transport cost, our estimations present strongly reduced omitted variable concerns. However, it may be the case that a destination experiencing a positive shock in imports of a specific product from a specific exporting country (note that any importer specific shock is captured by fixed effects) may react by increasing its tariff protection. In this case the ε parameter may be biased by endogeneity. To address this potential bias we adopt a Instrumental Variable (IV) approach instrumenting the *bilateral* tariff. As instrument for bilateral tariff, we use the average tariff imposed by other importing countries $n \neq j$ within the same continent of importer j on a given exporter-product ik: $\tau_{ijk}^{IV} = \frac{1}{N-1}\sum_{n \neq j}^{N-1} \tau_{ink}$, where N is the total number of countries composing the continent of importer j. This instrumental variable has the same variability as bilateral tariff τ_{ijk} and allows us to keep the same specification as in Equation 1. This IV can be considered valid: (i) if the amount of import of country j from i on product k does not affect the tariff scheme imposed by third countries n, and (ii) if the tariff imposed by third countries n affects the imports of j only through its effect on bilateral tariff τ_{ijk}.[30] The exclusion restriction (ii) is plausibly satisfied because any exporter specific diversion effect (it specific) implied by a change in the third country n tariff is captured by it fixed effects. Similarly, any *average* reaction in tariff imposition by third countries n towards a given exporter i is (partially) captured by exporter-year fixed effects. This makes exclusion restriction (i) plausibly valid.

As an alternative to the IV strategy we use lagged tariff variable to further reduce any endogeneity concern in section 2.3.1. Given the non-consecutive year nature of our dataset, we can safely argue that the contemporaneous level of imports is less likely to affect tariff imposition three years before.

A last concern is the composite nature of trade costs: geography (transport costs, contiguity), tariffs and non-tariff barriers. Our specification controls for distance between exporter and importer, as well as contiguity. The elasticity of transport cost to distance is indeed sector specific, but we rely on an estimation at the product level, which avoids imposing a common transport cost elasticity across products. Non-tariff barriers deserve a deeper discussion for two reasons. First, tariffs and Non-Tariff barriers may act as substitutes or complements. A country phasing out its tariffs may well tighten the restrictiveness of regulations at the border in order to cushion the competitive pressure of imports (Orefice 2017). Alternatively, certain countries may exhibit a complementarity of the two types of measures – in China applied tariff reductions were associated with the elimination of Non-Tariff barriers (Imbruno 2016). Second, were these two types of measures at the border set

[29] This strategy equals the inclusion of the average tariff imposed by third countries, $Third\ Country\ Tariff_{ijt} = \frac{1}{N-1}\sum_{n \neq i}^{N-1} \tau_{jnt}$, where N is the total number of exporting countries i. While this variable appears to be ijt specific, it is a simple combination of the average tariff imposed by third countries n and the bilateral tariff τ_{ijt}. So, the inclusion of exporter-year fixed effects and bilateral tariff subsumes the inclusion of the variable $Third\ Country\ Tariff_{ijt}$.

[30] Our IV is identical to the endogenous bilateral tariff if all the countries of a same continent belong to a custom union (in our definition of continent this is the case only for the EU). This does not represent a problem in estimation as far as bilateral imports of country j do not affect the bilateral tariff imposed by the overall custom union.

independently, the mere presence of a Non-Tariff Barrier would be an obstacle to increasing imports after a tariff cut. Against this background, one might want to control for the presence of Non-Tariff Barriers, but we know from the literature that related regulatory measures do not necessarily deter trade – certain regulations convey information on the traded products and thus facilitate trade. Hence, introducing a control for the presence of a Non-Tariff Barriers at destination for the considered product is hardly the solution. However, as Non-tariff Barriers are non-discriminatory (see e.g. the WTO agreement on Sanitary and Phyto-Sanitary measures), their presence can be captured, in an equation estimated at the product level, by a importer-time fixed effect. This is the strategy embraced in this paper.

2 Disaggregated Trade Elasticities to Tariffs

In this section we present the elasticities obtained for 5,052 products, computed over the period 2001-2016. The median of t-statistics is 3.3, and 79% of the estimated elasticities are significant.[31] We first address the problem of tariff elasticities estimated as *positive* and significant. Then we present evidence on tariff elasticity based on our baseline specification; and finally we also present the outcome of a series of robustness checks.

2.1 Interpreting positive elasticities

We estimate Equation 1 for each of the 5,052 HS-6 product lines using PPML estimator. Not surprisingly, not all the estimated elasticities are statistically significant with the same degree of confidence. We also obtain positive elasticity parameters for certain products. Table 4 reports descriptive statistics on the share of positive elasticity parameters statistically significant at 1%. Overall, 2.4% of elasticities significant at the 1% level are positive.[32] Such positive and significant elasticities occur for products concentrated in few very peculiar HS 2-digit chapters. We report in Table 4 the HS 2-digit chapters whose frequency of positive product elasticity is above the mean. Organic and inorganic chemicals, Nuclear reactors represent the lion's share in the total number of positive tariff elasticity. While in certain sectors, such as Nuclear reactors, deviations from the usual market forces were expected, in other cases, like Chemicals, these positive elasticities deserve further scrutiny. When prices hardly determine quantities, deviation from the perfect competition equilibrium have to be envisaged. A low degree of competition across exporting countries in these peculiar sectors might help

[31] More precisely, the percentage of significant elasticities is 79%, 73% and 63% at the 10-percent, 5-percent and 1-percent significance level. One can benchmark these results with Kee et al. (2008) using also HS6 data, although the estimation method and the period (1998-2001 instead of 2001-2016) differ. The corresponding figures are 71%, 66% and 57%. Their median t-stat is identical.

[32] The proportion rises to 4.1% and 5.5% respectively at the 5% and 10% significance level. In the analysis that follows and in the dataset we provide, we keep 1% significant elasticity only. Non-significant elasticities are reported as zero (as statistically non-different from zero). In the published version of the database, each positive HS6 tariff elasticity has been substituted by the average elasticity of its HS-4 heading (average across negative HS-6 specific elasticities within HS4). Concerned products are flagged. The database therefore contains four variables: (i) the HS 6-digit product category, (ii) the value of tariff elasticity, (iii) a dummy indicating whether the elasticity from the original estimation was actually a zero (i.e. non-significant), (iv) a dummy indicating whether the elasticity from the original estimation was positive.

predicting the occurrence of positive elasticities.

Table 4: Descriptive statistics of elasticity estimation. Frequency and number of positive estimated elasticities. Total and by HS 2-digit chapter (only HS-2 digit chapters with number of positive elasticity estimations above the mean are reported)

HS2 Chapter	Sector description	Frequency	Number
	Total	**2.4%**	**122**
3	Fish And Crustaceans, Molluscs And Other Aquatic Invertebrates	3.8%	4
12	Oil Seeds And Oleaginous Fruits; Miscellaneous Grains, Seeds And Fruit, Industrial Or Medicinal Plants	5.4%	2
25	Salt; Sulphur; Earths, Stone; Plastering Materials, Lime And Cement	2.9%	2
26	Ores, Slag And Ash	8.8%	3
27	Mineral Fuels, Mineral Oils And Products Of Their Distillation; Bituminous Substances	4.8%	2
28	Inorganic Chemicals	4.3%	7
29	Organic Chemicals	9.3%	31
37	Photographic Or Cinematographic Goods	9.1%	3
55	Man-Made Staple Fibres	1.9%	2
62	Apparel And Clothing Accessories	1.8%	2
63	Textiles, Made Up Articles; Sets; Worn Clothing And Worn Textile	5.8%	3
65	Headgear And Parts Thereof	22.2%	2
70	Glass And Glassware	3.1%	2
71	Natural, Cultured Pearls; Precious, Semi-Precious Stones; Precious Metals	3.9%	2
72	Iron And Steel	2.4%	4
73	Iron Or Steel Articles	2.4%	3
81	Metals; N.E.C., Cermets And Articles Thereof	4.2%	2
82	Tools, Implements, Cutlery, Spoons And Forks, Of Base Metal	3.0%	2
84	Nuclear Reactors, Boilers, Machinery And Mechanical Appliances;	2.6%	13
85	Electrical Machinery And Equipment And Parts Thereof	0.8%	2
87	Vehicles; Other Than Railway Or Tramway Rolling Stock	2.7%	2
90	Optical, Photographic, Cinematographic, Measuring, Checking, Medical Or Surgical Instruments And Apparatus	1.3%	2
91	Clocks And Watches And Parts Thereof	7.8%	4
96	Miscellaneous Manufactured Articles	4.2%	2

Note: This table reports descriptive statistics on estimated elasticities (as in equation 1). Frequency of statistically significant positive elasticities (at 99%) computed on the total of HS 6-digit lines within a HS-2 chapter.
Source: Authors' calculation.

Let us focus first on market structures as explanation for positive elasticity. Although the occurrence of positive elasticities represent only the 2.4% of the total sample of significant elasticities, we want to provide a characterization of the product categories where this problem appears. To this end we adopt a purely heuristic approach and run a probit model aimed at explaining the probability of having positive elasticity using proxies of market structures:

$$\mathbb{P}[\varepsilon_k > 0] = \beta_1 \mathbf{X}_k + \beta_2 \mathbf{M}_k + \beta_5 \mathbf{XM}_k + \epsilon_k \tag{2}$$

In Equation (2) the probability of obtaining a positive and significant (at 1%) tariff elasticity from Equation (1) depends on three sets of covariates: (i) exporters' characteristics in the international trade of product k ($\mathbf{X}_k$); (ii) importers' characteristics ($\mathbf{M}_k$); and (iii) country-pairs characteristics in the international trade of product k ($\mathbf{XM}_k$). Namely, the set of covariates $\mathbf{X}_k$ includes the number of exporting countries in a specific k, their concentration (measured with Herfindahl-Hirschmann index), and the average per capita GDP (weighted by total exports) of the exporter - here intended as a proxy for the technical level/quality of the exported products. Symmetrically, the set of covariates $\mathbf{M}_k$ includes the same variables but from the perspective of the importing countries. Finally, the set of covariates $\mathbf{XM}_k$ includes the number of bilateral zero-trade flows, and the average distance covered by a product in its international trade matrix tentatively accounting for sorting effects in relation with trade costs.[33]

Results reported in Table 5 confirm regularities explaining the observed deviation from the perfect competition equilibrium for certain product categories. First, products k with a highly concentrated set of exporters and/or importers (as revealed by HH index) are more likely to show positive tariff elasticity. In presence of a high market concentration, a reduction in tariffs imposed on a market may lead to unexpected results: an increase in the degree of competition at destination may push the incumbent exporters to exert an even higher effort in securing their presence at destination. In a model of imperfect competition and variable markups, firms decrease their markups and thus export prices when they lose market share (Atkeson & Burstein 2008). This translates in a negative relationship between tariffs and export price (see Fontagné et al. (2018)), which may offset the direct negative tariff effect on exports. A second interesting regularity emerging from Table 5 is the positive correlation between the average distance covered by a product and the probability of obtaining positive tariff elasticity. This is coherent with the idea that products shipped very far away are high-quality products (Hummels & Skiba 2004) often characterized by low or even positive elasticities. Coherent with this argument, we also find that products traded by relatively high-income countries (as revealed by the average income of exporters and importers) show higher probability of having positive tariff elasticity. On the exporter side this

[33] We consider here the average distance across country-pairs in a given products k, weighted by trade flows. Since the estimated elasticity σ does not vary over time, all the explanatory variables have been expressed as average over the time period.

mirrors the technological level of goods, while the importing side echoes the recent literature on non-homothetic preferences (Markusen 2013) whereby markups are increasing in the destination income per capita (Bertoletti, Etro & Simonovska 2018).

Table 5: Probit regression on the probability of obtaining positive and significant tariff elasticity.

Dep var:	$\mathbb{P}[\varepsilon_k > 0]$		
	(1)	(2)	(3)
HH index exporters	0.790**	0.912**	1.145***
	(0.347)	(0.367)	(0.429)
HH index importers	2.215***	2.798***	2.976***
	(0.493)	(0.540)	(0.597)
Avg per capita GDP exporters (ln)	0.249***	0.182*	0.167
	(0.095)	(0.108)	(0.121)
Avg per capita GDP importers (ln)	0.406***	0.447***	0.443***
	(0.144)	(0.151)	(0.169)
Avg distance across country-pairs (ln)	0.389***	0.295**	0.245*
	(0.115)	(0.125)	(0.141)
N. zero-trade flows (ln)	0.416	2.260	2.467
	(1.451)	(1.589)	(1.782)
N. exporting countries (ln)	-0.922	-2.409	-2.496
	(1.372)	(1.499)	(1.697)
N. importing countries (ln)	-31.79	-10.29	22.19
	(35.88)	(38.61)	(53.58)
HS 1-digit FE	no	yes	no
HS 2-digit FE	no	no	yes
Observations	5,050	4,526	3,594

Note: Dependent variable equal to one if the estimated elasticity is positive and significant at 1% level. Robust standard errors in parentheses. *** $p < 0,01; **p < 0,05; *p < 0,1$. The number of observations decreases from specification (1) to (3) because the inclusion of HS 1-digit and 2-digit fixed effects implies the drop of chapters and sectors having only negative elasticities (i.e. $\mathbb{P}[\varepsilon_k > 0] = 0$ in all k within a HS1 and HS2 chapter.)

2.2 Baseline results

The empirical distribution of trade elasticities, after excluding positive and non-significant one, is centered around -6 as shown in Figure 1 and can be very large for certain products (beyond -20).[34] They are more dispersed in the manufacturing industry than in agriculture, but centered around the same value (see Appendix Figure A2). By comparing the tariff elasticity distribution between PPML and OLS estimator, we find that the zero trade flows problem (heteroskedasticity) implies a negative bias in the magnitude of tariff elasticity, as shown by the comparison of figures 1 and A1. Another interesting characterization of tariff elasticities by type of product emerges by using Rauch classification on differentiated *vs* homogeneous products. As expected,

[34]The empirical distribution reported in Figure 1 does not consider positive and non-significant elasticities. The left tail of the empirical distribution reported in Figure 1 has been cut at -25 to the sake of readability of the figure. However only for a very few number of HS6 products (3% of total product lines) we obtain even larger tariff elasticities.

Figure A3 shows higher and more dispersed tariff elasticities for homogeneous than for differentiated products.

Our method does not allow us to estimate the whole set of elasticities however. Indeed, for some HS-6 digit positions, the bilateral variability in tariff is not sufficient to estimate the parameter ε in Equation 1. Table 6 shows, for each HS section, the number of HS6 positions and the number of estimated elasticities. In most of the sectors, the method is successful. In 5 sections of the HS, all elasticities are estimated. For Pulp of wood or other cellulosic materials, only two product level elasticities are not identified out of 144 product categories; the same observation can be made for Articles of stone plaster ceramic and glass (respectively 2 out of 143). One sector is more problematic (Products of chemical industries): here, only 740 elasticities are estimated out of 789 product categories.[35]

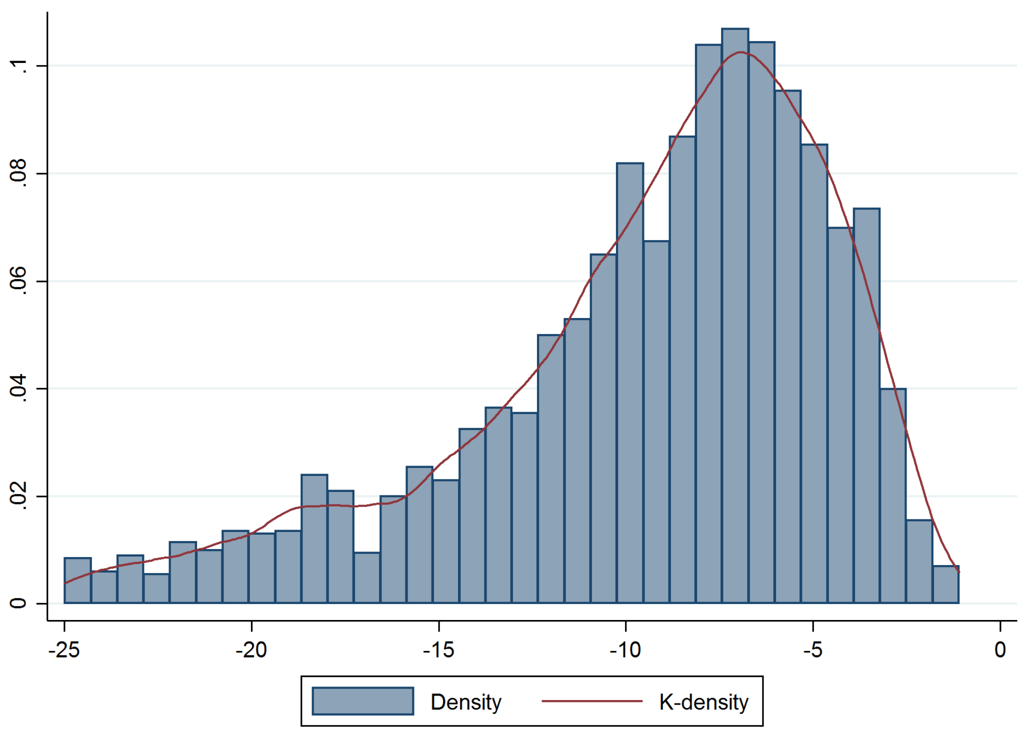
The average elasticities within the different Sections of the HS (average of the product level elasticities within the Section) exhibit values in line with the expectations: for rather standardized products like Plastic and Rubber the average elasticity is close to -9, while in highly differentiated products like Machinery and Electrical products this is -4.7. The largest elasticities ("min" in the Table) can reach very high values. Some of these may be considered outliers in estimations but are anyway kept in the database.

The dispersion of estimated elasticities within a sector can be further illustrated by focusing on the sector – Textile – comprising the largest number of HS6 categories.[36] The average dispersion across the 791 estimated elasticities (out of 801 product categories) is 7.42. We show in Table 7 the average elasticities by HS2 within the Textile industry. The trade elasticity is very large for Man-made filaments or Man-made staple fibres (respectively -9.90 and -9.80) and much lower for Apparel and clothing accessories not knitted or crocheted, for Textile, made up articles, sets, worn clothing and worn textile articles and Apparel and clothing accessories knitted or crocheted (respectively -4.41, -3.96, -2.24).

[35]Descriptive statistics on tariff elasticity by HS section do not consider products with positive elasticities.

[36]For the clarity of exposition, we keep textile as an example. However product specific elasticities are highly heterogeneous in all the products categories. Descriptive statistics on tariff elasticity for textile products do not consider products with positive elasticities.

Figure 1: Empirical distribution of tariff elasticity across all sectors (PPML estimations)



Source: Authors' calculations. Note: empirical distribution calculated on negative tariff elasticities. Positive and non-significant tariff elasticities not considered.

Table 6: Descriptive statistics of elasticity by HS section

Section	Description	Average	Std Dev	Min	N. of HS6	N. of HS6 non-missing σ
I	Live Animals and Animal Products	-6.22	9.35	-68.72	228	223
II	Vegetable Products	-5.66	5.05	-22.48	256	250
III	Animal or vegetable fats and oils	-7.54	8.84	-46.70	45	44
IV	Prepared foodstuffs, beverages and tobacco	-6.45	4.92	-30.54	193	193
V	Mineral products	-13.83	19.73	-132.80	148	138
VI	Products of chemical industries	-8.12	11.61	-119.45	789	740
VII	Plastic and articles thereof	-8.98	8.20	-72.70	211	211
VIII	Raw hides and skins, leather and article thereof	-4.33	5.41	-18.36	69	68
IX	Wood/Cork and articles of Wood/Cork;	-7.19	7.92	-50.52	93	93
X	Pulp of wood or other cellulosic materials	-9.27	8.37	-64.53	144	142
XI	Textile and textile articles	-6.80	7.42	-52.24	801	791
XII	Footwear, Headgear, Umbrellas and prepared feathers	-3.49	3.50	-11.74	49	46
XIII	Articles of stone, plaster, ceramic and glass	-6.30	5.53	-25.55	143	141
XIV	Natural cultured pearls and precious stones and metals	-8.37	13.52	-66.25	51	49
XV	Base metals and articles of base metals	-7.87	10.31	-64.73	568	556
XVI	Machinery and mechanical appliances and electrical machinery	-4.71	6.25	-40.50	769	754
XVII	Vehicles, Aircraft and transport equipment	-9.00	9.72	-42.54	131	128
XVIII	Optical, photographic, precision and medical instruments	-3.76	5.94	-50.39	217	210
XIX	Arms and ammunitions	-4.83	6.54	-14.91	20	20
XX	Miscellaneous	-4.65	4.43	-15.67	118	116
XXI	Works of art	-4.64	6.06	-13.20	7	7

Note: This table reports descriptive statistics (mean, standard deviation, min and non-missing value) on ε parameter estimated as in equation 1, for each HS section. Descriptive statistics reported in this table are calculated excluding positive elasticities.
Source: Authors' calculation.

Table 7: Descriptive statistics of elasticity for Textile sector by HS 2-digit chapter.

Chapter HS 2-digit	Average	Std Dev	Min
Silk	-1.33	3.76	-10.65
Wool, Fine or Coarse Animal Hair; Horsehair yarn and woven	-15.70	14.53	-52.24
Cotton	-8.90	8.12	-34.60
Vegetables textile fibres	-7.57	10.88	-30.49
Man-made filaments; strips and like of man-made textile materials	-9.90	8.72	-49.69
Man-made staple fibres	-8.80	7.42	-33.75
Wadding, felt and nonwovens, special yars; Twine, cordage ropes and cables	-7.38	4.22	-16.23
Carpets and other textile floor coverings	-4.87	4.20	-13.77
Fabrics; special woven fabrics, tufted textile fabrics, lace, tapestries, trimmings, embroidery	-4.28	4.37	-19.22
Textile fabrics; impregnated, coated, covered or laminated; textile articles of a kind suitable for industrial use	-9.22	6.66	-25.43
Fabrics; knitted or crocheted	-6.11	2.55	-9.95
Apparel and clothing accessories; NOT knitted or crocheted	-4.41	3.37	-13.89
Apparel and clothing accessories; knitted or crocheted	-2.24	2.43	-9.82
Textile , made up articles; sets; worn clothing and worn textile articles	-3.96	3.27	-10.17

small*Note*: This table reports descriptive statistics (mean, standard deviation and min) on ε parameter estimated as in equation 1, for each HS 2-digit chapter within section XI. Descriptive statistics reported in this table are calculated excluding positive elasticities.
Source: Authors' calculation.

2.3 Robustness checks

2.3.1 Endogeneity

We already mentioned the issue of endogeneity. Technically, two problems of endogeneity have to be addressed when it comes to evaluating the response of trade to tariff shocks. First, since liberalization episodes generally start by lowering tariffs for products or industries hardly affected by foreign competition, tariff cuts may have limited effect. As discussed in the previous section, the inclusion of country-year fixed effects controlling for any unobserved country-year specific factors, and the geographic controls capturing the bilateral transport cost reduce considerably this omitted variable problem. Recall also that estimations are performed at the product level, meaning that the country-year characteristics so controlled pertain to products or industries, as needed.

The second problem is that higher tariffs opposed to certain exporting countries in certain sectors may aim to extract rents from an exporter exerting a high market power, which brings us back to the discussion of market structures above. The political economy of protection also provides a rationale for endogenous tariffs: domestic industries affected by an increasing competition of imports will lobby for protection. Accordingly, tariffs should vary with the inverse penetration ratio and price elasticity of imports (Gawande & Bandyopadhyay 2000). The associated reverse causality may potentially bias estimations of ε. If an imported country sets the level of tariff protection based on the level of imports from a specific exporter, imports and tariff may show up as *positively* correlated at the detailed level of the product-partner.

At the level of detail considered here (HS6 products), the penetration ratio is not observable as we do not have information on expenditures in the importing country. This excludes any instrumentation method based on this usual theoretical argument. Two solutions may be proposed on this respect. First, a 2SLS approach can be used whereby one instruments bilateral tariff with the average tariff imposed by other importing countries $n \neq j$, within the same continent of importer j, on a given exporter-product ik. This is highly correlated with the bilateral tariff τ_{ijkt} (relevant IV), and it does not affect directly the bilateral imports of country i from j (validity of the IV). See section 1.4 for detailed discussion on the validity of our IV. Alternatively, one can resort on lagged variables in line with Shapiro (2016), who estimates trade elasticities for 13 sectors using shipping costs (not trade policy).

Tariff elasticities obtained by 2SLS are reported in Figure A4, dashed line. Using 2SLS approach, the average tariff elasticity is slightly lower (in absolute terms) than that obtained by PPML estimations: reverse causality does not smooth the trade elasticity to tariff.[37] In other words, we can reject the hypothesis that bilateral tariffs are set higher as a response of the competitive pressure of the exporter. As a further robustness check, we computed the average tariff imposed by other importers in the same MAcMap-HS6 *reference group*

[37] Indeed, if reverse causality was playing a role in our estimations, then after controlling for it with 2SLS, we should have obtained even stronger tariff elasticities (more negative). We actually obtain the opposite.

of the importer j. Results are reported in appendix Figure A5 and confirm what is obtained with the baseline IV based on continent. In Figure A6 we finally compare our baseline PPML elasticity estimations with those obtained by using three-year lag tariffs.[38] Tariff elasticity distribution using contemporaneous and lagged tariffs do not differ considerably comforting the conclusion that the usual endogeneity issue due to the potential reverse causality problem does not invalidate our results. Notice however that in the figures discussed here, we report only negative elasticities. The problem of positive elasticities discussed above remains for a bunch of products even after addressing endogeneity problem, and calls for further study of market structures for the concerned products or sectors.

We now aim at quantifying the usual aggregation bias by computing elasticities at different levels of detail of the product classification.

2.3.2 Product aggregation

In Figure A7 we replicate the exercise discussed in section 1.4 but using HS 4-digit rather than 6-digit specific data to estimate the trade elasticity. Namely, we aggregated imports by summing across HS6 within HS4 positions for each country-pair: we use the simple average tariff at the HS4 level for each importer-exporter pair. Tariff elasticities at the HS4 level reported in Figure A7 show the same empirical distribution as baseline results in Figure 1. We also replicate the same exercise and estimated the tariff elasticity by HS 2-digit chapter (summing imports and averaging tariffs across HS-6 within HS 2-digit chapter). Results, reported in Figure A8 show a less dispersed distribution of elasticities distributed again around the same value (about -6). This further supports the absence of aggregation bias in tariff elasticity. In order to compute gains from trade *à* la Arkolakis et al. (2012) reported in section 3, we also produce tariff elasticity following aggregate TiVA sector aggregation. Results from this last sector aggregation are provided in Table A3 by simple average across HS6 specific tariff elasticities within each TiVA sector. Pure service oriented sectors (such as Construction, Wholesales, hotel and restaurants, etc.) have indeed been excluded.

2.3.3 Conditioned on RTA

So far we based our evidence on Equation 1, which does not control for the presence of RTA among trade partners. In Table 2 we showed that up to one quarter of bilateral tariffs were different from the MFN. This difference is an important source of variation of our independent variable. Consequently, any preferential market access is then captured by applied tariffs and our trade elasticity may simply reflect the impact of RTAs. Moreover, the presence of a RTA may go beyond a simple market access effect. RTAs are signal of good political and business relationships among RTA's partners, possibly consolidated in mutual recognition of standards and certification

[38] Remember that MAcMap-HS6 provide tariff data in years 2001, 2004, 2007, 2010, 2013 and 2016.

procedures for instance. This may affect bilateral trade and then imply an omitted variable problem in Equation 1. To address this potential concern, in Figure A9 we compare baseline elasticity distribution (continuous line) with the empirical distribution of tariff elasticities after controlling for the presence of RTA (dashed line). Our main results are robust.

Another robustness test aims at keeping only exporting countries having enough variation in the tariffs faced at destination. In Figure A10 we show the empirical distribution of tariff elasticities obtained using a sub-sample of exporting countries having more than five trade partners (for a given product). By the same token, keeping the sub-sample of more productive exporters (those exporting toward more than five-destinations), we reduce the selection bias in the tariff elasticity estimation by relying on a more homogeneous set of exporters. Figure A10 shows the empirical distribution of tariff elasticities: our main results are robust.

2.3.4 Elasticity using Trade Volumes

Finally, in Figure A11 we compare tariff elasticity distributions computed on trade quantities (tons) *vs* values (in thousands of US dollars). This comparison indirectly shows the average pass through of countries across products. Indeed, if exporters were to fully pass-through tariffs in their prices, then tariff elasticity based on values and quantities would differ only by one. Figure A11 shows that the two elasticity distributions have only slight different average; i.e. trade quantities react less than expected (difference in average elasticity less than one). This result, indirectly suggesting the presence of small/incomplete pass-through, is in line with Fontagné et al. (2018) using French exporters level data, but contrasts with Amiti et al. (2019) who observe “little -to-no impact” of the tariffs on the prices charged by exporters to the US market during the 2017-18 period.[39]

3 Gains from trade with heterogeneous elasticities

The strong heterogeneity in tariff elasticity across products showed so far raises the question of whether using sector specific elasticity changes the evaluation of the gains from trade as obtained by Arkolakis et al. (2012) - ACR - methodology. Giri et al. (2018) examine whether sectoral heterogeneity of trade elasticity delivers systematically higher gains from trade. The answer depends on the combination of the trade elasticity, the share of sectors in value added and the penetration of imports. This section tentatively sorts out this question. We evaluate the gains from trade obtained using trade elasticities *heterogeneous* across sectors, and compare with those obtained using *homogeneous* (sector invariant) elasticity.

To proceed, we follow closely Arkolakis et al. (2012) and compute the gains from trade as the negative of

[39] Amiti et al. (2019) regress the change in the logarithm of the unit value on the change in the power of the applied tariff on imports over the same period, while Fontagné et al. (2018) regress in their first stage the unit value of the core exported HS6 product of the firm on (the power of) the applied tariff, using yearly data. In the latter case it is shown that a 10% increase in tariff implies a 3.2% reduction in the export price.

moving to autarky, with heterogeneous sectors. The change in real income is related to the total expenditure devoted to domestic production (domestic market share) and the trade elasticity. We use TiVA (OECD) data to compute both the share of total expenditure of country j devoted to domestic production (i.e. λ_{jj} in ACR), and the consumption share of country j in sector s (i.e. η_{js}, the upper-tier in the consumer utility in ACR). Then we compare the ex-ante evaluation of welfare gain obtained using heterogeneous elasticity with the case of homogeneous elasticity across sectors (average ε across sectors).[40] Everything else being equal, the magnitude of the gains is indeed increasing in the dispersion of sectoral elasticities. However, the extent of the bias in the estimation of welfare gains also depends on the country-sector share of domestic expenditure (the inverse of the import penetration ratio in the sector) and consumption shares.

Results from this exercise are showed in Figure 2. In the vertical axis we report the extent of the bias in welfare gains evaluation, calculated as the difference in welfare change using respectively heterogeneous elasticity ($\widehat{W^{Hetero}}$) and homogeneous elasticity ($\widehat{W^{Homog}}$) - based on the average trade elasticity in our dataset. In the horizontal axis we rank countries by (the logarithm of) per capita income in 2010. Figure 2 shows that the under-estimation of welfare gains using average homogeneous trade elasticity is increasing in per-capita income. Also, magnitude and dispersion of the bias in welfare evaluation are larger for high income countries. All in all, the dispersion of observations in Figure 2 suggests that the bias is far from being systematic. Everything else being equal in terms of import penetration, having high consumption share in low elastic sectors (i.e. where trade elasticity is smaller than the average) magnifies the gains from trade. And for a given consumption share, a high penetration of imports in low elastic sectors maximizes the gains from trade.

Figure 3 illustrates how the difference between sector specific and homogeneous elasticity (horizontal axis) affects the sectoral estimation of gains from trade (vertical axis) for selected countries (US, Germany, China and India). In sectors where trade elasticity is below average, using homogeneous trade elasticity implies a downward bias in the welfare gains from trade estimations – and conversely in sectors where trade elasticity is above average.

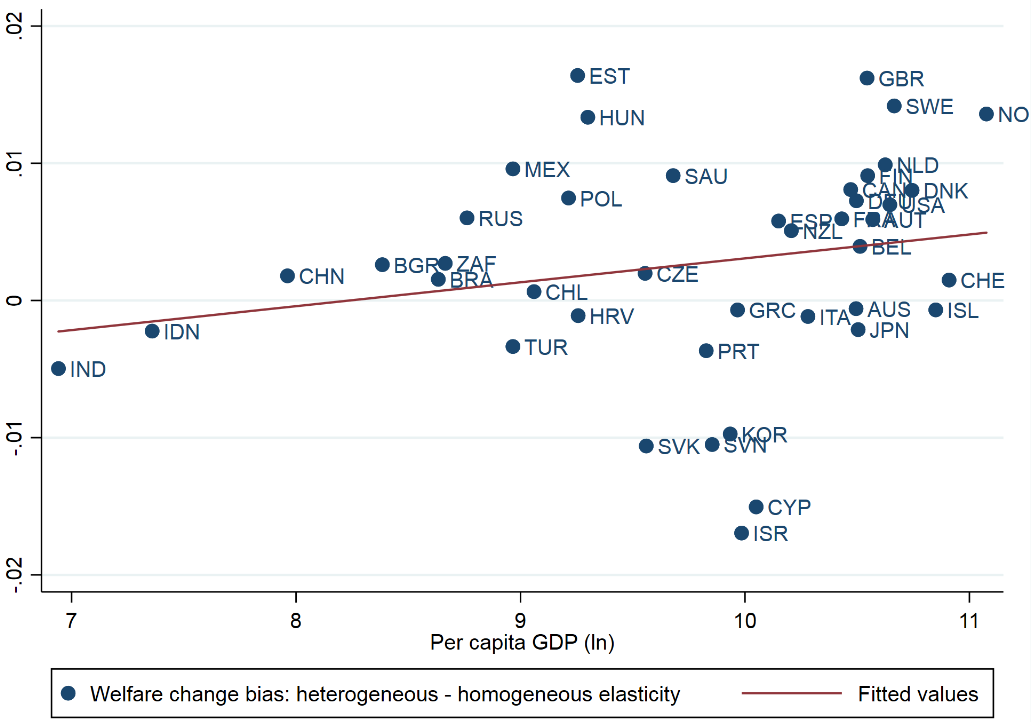
Finally, in a robustness check reported in the appendix section, we adopt homogeneous trade elasticity from three benchmark papers: (i) Feenstra et al. (2014) finding an elasticity governing the substitution between varieties of foreign goods equal to 4.4; (ii) Bas et al. (2017) who find average elasticity around 5; and Romalis (2007) who finds an elasticity equal to 8.5.[41] See Appendix Tables A4 and A5. The comparison of column 1 and subsequent confirms the large impact of the set of trade elasticity estimates used, on the results of the ex-ante evaluation of welfare changes.[42]

[40] To this end HS 6-digit trade elasticities have been aggregated (by averaging) at TiVA sector level.

[41] Depending on the specification, Romalis (2007) finds elasticities of substitution spanning from 6 to 11 - see Tables 3A and 3B in Romalis (2007). Here we take the average of these elasticity as a benchmark.

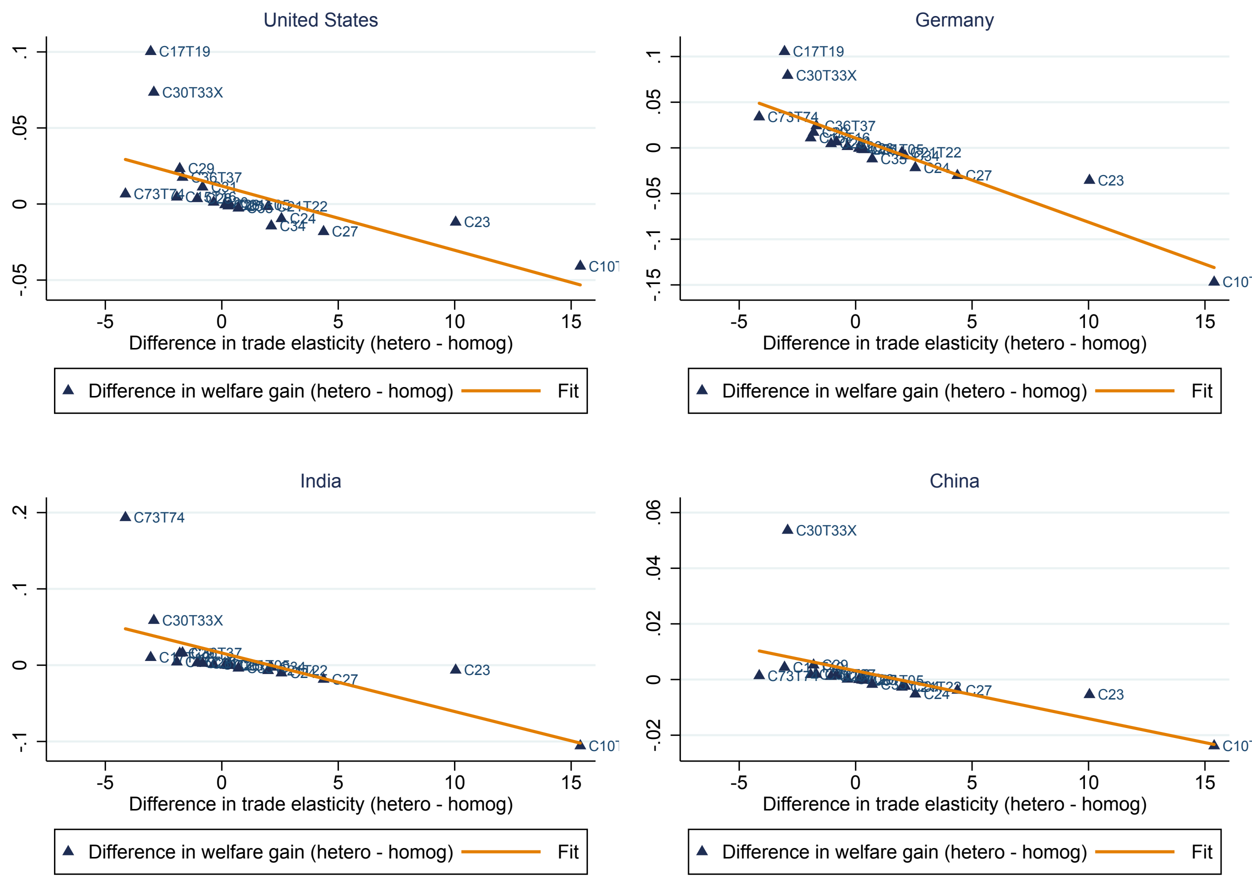
[42] Tariff elasticity cannot be estimated for pure service sectors where tariffs are absent. So the welfare change evaluations reported here consider only TiVA manufacturing sectors (see table A3 for the list of elasticity parameters by TiVA sector). We keep all TiVA sectors covering at least one HS 6-digit tariff elasticity. That's why in table A3 we also report some service oriented sectors. These results are therefore not fully comparable with a pure general equilibrium exercise as the one reported in Arkolakis et al. (2012)

Figure 2: Correlation between bias in welfare change evaluation (heteregeneous vs homogeneous elasticity) and per capita GDP in 2010.



Source: Authors' calculations. The vertical axis reports the difference in the welfare change computed using heterogeneous elasticity ($\widehat{W^{Hetero}}$) and homogeneous elasticity ($\widehat{W^{Homog}}$) based on the average $(1-\sigma_s)$ across products in our dataset.

Figure 3: Correlation between bias in sectoral welfare change evaluation (heteregeneous vs homogeneous elasticity) and difference to the mean trade elasticity, for four countries (2010).



Source: Authors' calculations. The vertical axis reports the difference in the welfare change computed using heterogeneous elasticity ($\widehat{W^{Hetero}}$) and homogeneous elasticity ($\widehat{W^{Homog}}$) based on the average $(1 - \sigma_s)$ across products in our dataset.

4 Conclusion

The main contribution of this paper is to offer an estimate of trade elasticity for the recent period and at the product level, by exploiting the variation over the period 2001-2016 in bilateral applied tariffs for each product category for the universe of available country pairs. We combine two databases covering the universe of exporters, importers and products at the finest level of disaggregation (6-digit of the Harmonized system). Although we obtain average elasticity in line with the one used in the literature, we also shed light on the large variation around this value generally used to calibrate empirical exercises. We illustrate the impact of such calibration of elasticities with a simple exercise in line with Arkolakis et al. (2012). For the sake of further utilization by the profession, this unique set of elasticities is made available on a dedicated web-page.

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that considers also service sectors in the calculation of the import penetration. In Arkolakis et al. (2012) the absence of elasticity parameter for service sectors is not an issue as they consider a homogeneous elasticity parameter for all sectors (manufacturing and service).

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A Appendix

Table A1: Descriptive statistics. Average tariff by HS section and year.

Section	Description	2001	2004	2007	2010	2013	2016
I	Live Animals and Animal Products	17.4	17.6	16.4	15.5	14.8	14.2
II	Vegetable Products	15.3	15.2	13.5	13.0	12.5	11.7
III	Animal or vegetable fats and oils	13.6	13.6	12.0	11.0	10.6	10.4
IV	Prepared foodstuffs, beverages and tobacco	21.4	21.6	19.8	18.9	17.5	16.9
V	Mineral products	5.5	5.3	4.7	4.4	4.2	3.9
VI	Products of chemical industries	6.3	6.1	5.0	4.7	4.5	4.3
VII	Plastic and articles thereof	9.3	9.0	7.6	7.2	7.0	6.7
VIII	Raw hides and skins, leather and article thereof	11.2	11.0	9.7	9.5	9.1	8.6
IX	Wood/Cork and articles of Wood/Cork;	11.0	10.8	9.2	8.9	8.5	8.0
X	Pulp of wood or other cellulose materials	8.3	8.2	7.2	7.0	6.6	6.2
XI	Textile and textile articles	14.6	13.1	11.8	11.4	10.9	10.5
XII	Footwear, Headgear, Umbrellas and prepared feathers	16.6	16.2	14.4	14.0	13.3	12.6
XIII	Articles of stone, plaster, ceramic and glass	11.8	11.5	10.3	9.9	9.6	9.2
XIV	Natural cultured pearls and precious stones and metals	11.4	11.0	9.5	9.5	9.0	8.5
XV	Base metals and articles of base metals	8.3	8.1	7.1	6.8	6.5	6.2
XVI	Machinery and mechanical appliances and electrical machinery	6.9	6.8	5.8	5.4	5.1	4.9
XVII	Vehicles, Aircraft and transport equipment	9.7	9.4	8.1	7.6	7.1	6.8
XVIII	Optical, photographic, precision and medical instruments	8.6	8.5	7.3	6.9	6.6	6.3
XIX	Arms and ammunitions	18.2	18.2	16.5	15.9	15.1	13.5
XX	Miscellaneous	14.2	13.9	12.3	12.1	11.6	11.3
XXI	Works of art	10.8	10.5	9.4	9.4	9.0	8.5

Note: This table reports the simple average tariffs by HS section and year.
Source: MAcMap-HS6, authors' calculation.

Table A2: Descriptive statistics. Standard deviation of tariffs by HS section and year.

Section	Description	2001	2004	2007	2010	2013	2016
I	Live Animals and Animal Products	28.9	31.4	31.8	28.5	27.4	26.2
II	Vegetable Products	29.2	30.3	26.2	24.6	23.3	23.1
III	Animal or vegetable fats and oils	17.8	19.2	17.5	16.1	16.1	16.1
IV	Prepared foodstuffs, beverages and tobacco	41.4	46.9	47.8	45.6	39.9	38.6
V	Mineral products	7.4	7.5	6.7	6.7	11.3	6.4
VI	Products of chemical industries	9.2	10.0	8.6	8.5	8.2	7.4
VII	Plastic and articles thereof	10.5	11.1	9.6	9.5	9.6	8.9
VIII	Raw hides and skins, leather and article thereof	13.5	14.0	13.0	13.1	12.9	11.3
IX	Wood/Cork and articles of Wood/Cork;	16.4	16.7	10.8	10.7	10.4	9.8
X	Pulp of wood or other cellulose materials	9.6	10.7	9.3	9.3	8.8	8.5
XI	Textile and textile articles	34.6	14.3	13.9	13.3	13.3	13.1
XII	Footwear, Headgear, Umbrellas and prepared feathers	15.6	16.8	14.7	14.4	13.9	13.3
XIII	Articles of stone, plaster, ceramic and glass	11.9	12.9	11.3	11.2	11.0	10.7
XIV	Natural cultured pearls and precious stones and metals	13.8	13.7	12.2	12.4	12.0	11.6
XV	Base metals and articles of base metals	9.2	10.4	8.8	8.9	8.6	8.3
XVI	Machinery and mechanical appliances and electrical machinery	8.5	10.2	8.1	8.1	7.8	7.6
XVII	Vehicles, Aircraft and transport equipment	14.6	15.1	12.5	11.9	11.5	10.5
XVIII	Optical, photographic, precision and medical instruments	10.2	11.7	9.5	9.5	9.2	9.0
XIX	Arms and ammunitions	26.1	27.0	25.4	24.9	21.2	15.1
XX	Miscellaneous	12.8	13.7	12.2	12.1	11.9	11.6
XXI	Works of art	12.6	12.5	11.3	11.4	11.2	11.0

Note: This table reports the standard deviation of tariffs by HS section and year.
Source: MAcMap-HS6, authors' calculation.

Table A3: Trade elasticity by TiVA sectors used in the calculation of gain from train in section 3.

TiVA Industry code	Heading	Average elasticity
C01T05	Agriculture, hunting, forestry and fishing	-7.24
C10T14	Mining and quarrying	-22.27
C15T16	Food products, beverages and tobacco	-4.94
C17T19	Textiles, textile products, leather and footwear	-3.82
C20	Wood and products of wood and cork	-6.52
C21T22	Pulp, paper, paper products, printing and publishing	-8.86
C23	Coke, refined petroleum products and nuclear fuel	-16.91
C24	Chemicals and chemical products	-9.43
C25	Rubber and plastics products	-7.15
C26	Other non-metallic mineral products	-7.02
C27	Basic metals	-11.24
C28	Fabricated metal products	-5.82
C29	Machinery and equipment, nec	-5.07
C30T33X	Computer, electronic and optical equipment	-3.96
C31	Electrical machinery and apparatus, nec	-6.05
C34	Motor vehicles, trailers and semi-trailers	-9.00
C35	Other transport equipment	-7.59
C36T37	Manufacturing nec; recycling	-5.19
C40T41	Electricity, gas and water supply	0
C73T74	R&D and other business activities	-2.73
C90T93	Other community, social and personal services	-3.23

Note descriptive statistics reported in this table are calculated excluding positive elasticities. We used all aggregated TiVA sectors that include at least one tariff HS 6-digit elasticity. Pure service oriented TiVA sectors without any HS 6-digit estimated elasticity (i.e. any tariff available) have been excluded.

Table A4: Ex ante welfare evaluation: moving to autarky. Change in log real income across non-OECD countries. ACR formula with homogeneous trade elasticity.

	Homogeneous elasticity across sectors:			
	Average $(1-\sigma_s)$	*Feenstra et al (2014)*	*Bas et al.(2017)*	*Romalis (2007)*
Argentina	0.027	0.042	0.037	0.022
Brazil	0.016	0.025	0.022	0.013
Bulgaria	0.083	0.127	0.113	0.068
China	0.014	0.022	0.019	0.011
Croatia	0.057	0.088	0.078	0.047
Cyprus	0.201	0.296	0.266	0.166
India	0.031	0.048	0.043	0.025
Indonesia	0.032	0.050	0.044	0.026
Romania	0.057	0.088	0.078	0.046
Russian Federation	0.034	0.053	0.047	0.028
Saudi Arabia	0.101	0.154	0.136	0.083
South Africa	0.049	0.075	0.067	0.040

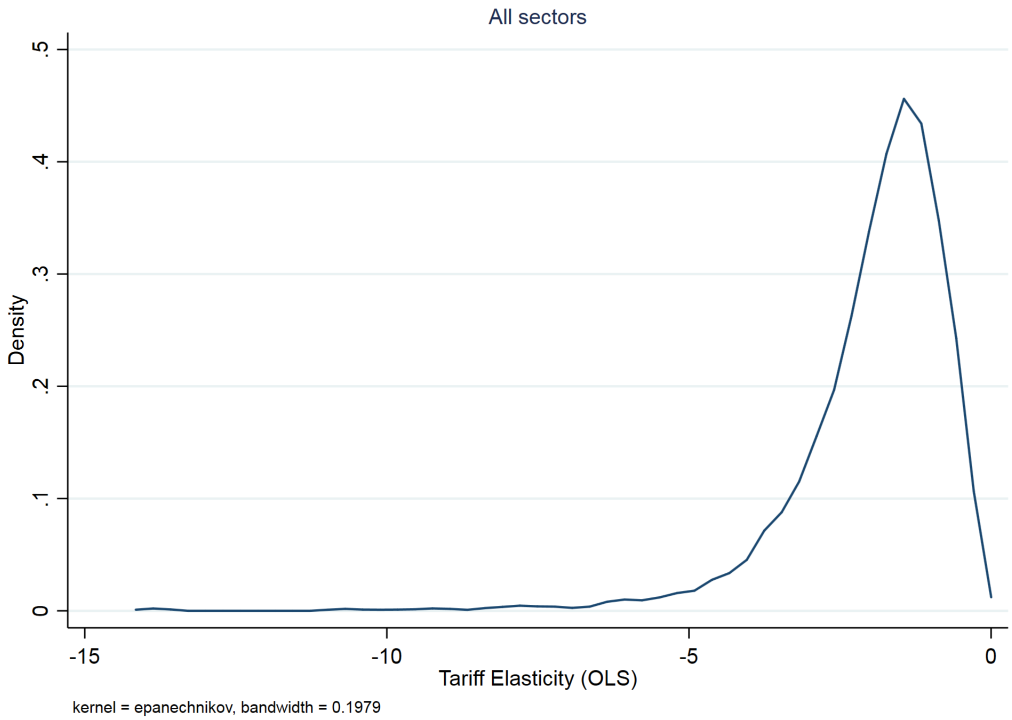
Note: In computing the cost of autarky we follow ACR(2010) sections 3.3 and 5.1. To compute change in welfare following elasticity in Feenstra et al. (2014), Bas et al. (2017) and Romalis (2007) we used $(1-\sigma)$ respectively equal to 4.4, 5 and 8.5. *Source*: Authors' calculation.

Table A5: Ex ante welfare evaluation: moving to autarky. Change in log real income across OECD countries. ACR formula with homogeneous trade elasticity.

	Homogeneous elasticity across sectors:			
	Average $(1-\sigma_s)$	*Feenstra et al (2014)*	*Bas et al.(2017)*	*Romalis (2007)*
Australia	0.055	0.085	0.075	0.045
Austria	0.070	0.108	0.095	0.057
Belgium	0.059	0.090	0.080	0.048
Canada	0.081	0.124	0.110	0.066
Chile	0.067	0.103	0.092	0.055
Czech Republic	0.073	0.111	0.099	0.059
Denmark	0.061	0.093	0.082	0.049
Estonia	0.098	0.149	0.133	0.080
Finland	0.067	0.103	0.091	0.055
France	0.057	0.087	0.077	0.046
Germany	0.052	0.081	0.071	0.043
Greece	0.095	0.144	0.128	0.077
Hungary	0.113	0.171	0.152	0.092
Iceland	0.116	0.175	0.156	0.095
Ireland	0.118	0.178	0.158	0.096
Israel	0.093	0.142	0.126	0.076
Italy	0.050	0.077	0.068	0.040
Japan	0.028	0.043	0.038	0.023
Luxembourg	0.274	0.394	0.356	0.228
Mexico	0.066	0.102	0.090	0.054
Netherlands	0.058	0.089	0.079	0.047
New Zealand	0.051	0.079	0.070	0.042
Norway	0.064	0.099	0.088	0.052
Poland	0.065	0.100	0.088	0.053
Portugal	0.082	0.126	0.111	0.067
Slovakia	0.114	0.172	0.153	0.093
Slovenia	0.105	0.159	0.141	0.086
South Korea	0.055	0.084	0.075	0.045
Spain	0.065	0.100	0.089	0.053
Sweden	0.071	0.109	0.097	0.058
Switzerland	0.090	0.137	0.122	0.073
Turkey	0.036	0.056	0.050	0.030
United Kingdom	0.077	0.117	0.104	0.063
United States	0.035	0.055	0.048	0.029

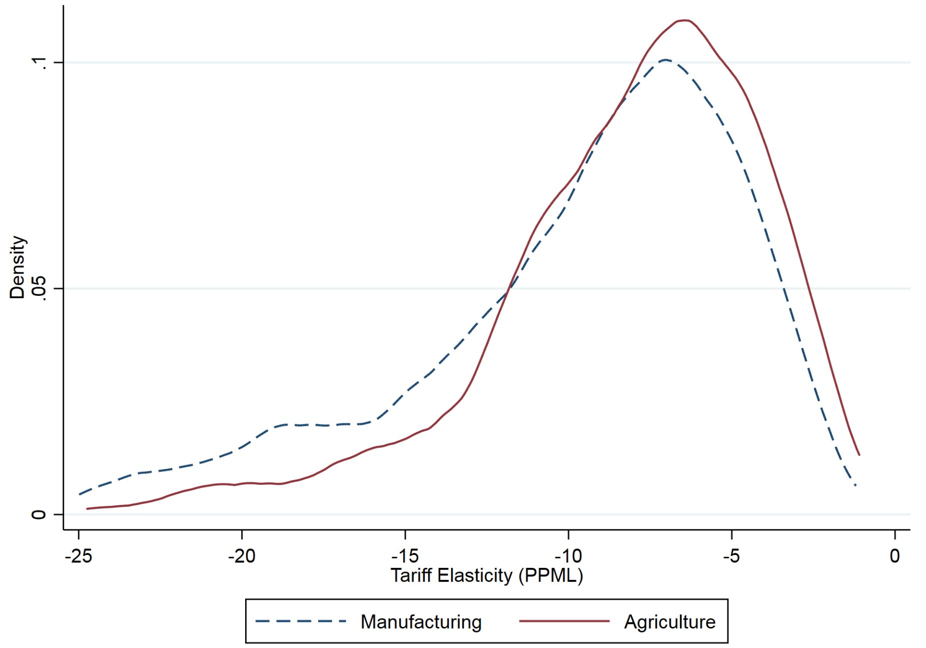
Note: In computing the cost of autarky we follow ACR(2010) sections 3.3 and 5.1. To compute change in welfare following elasticity in Feenstra et al. (2014), Bas et al. (2017) and Romalis (2007) we used $(1-\sigma)$ respectively equal to 4.4, 5 and 8.5. *Source*: Authors' calculation.

Figure A1: Empirical distribution of tariff elasticity across all sectors. OLS estimations.



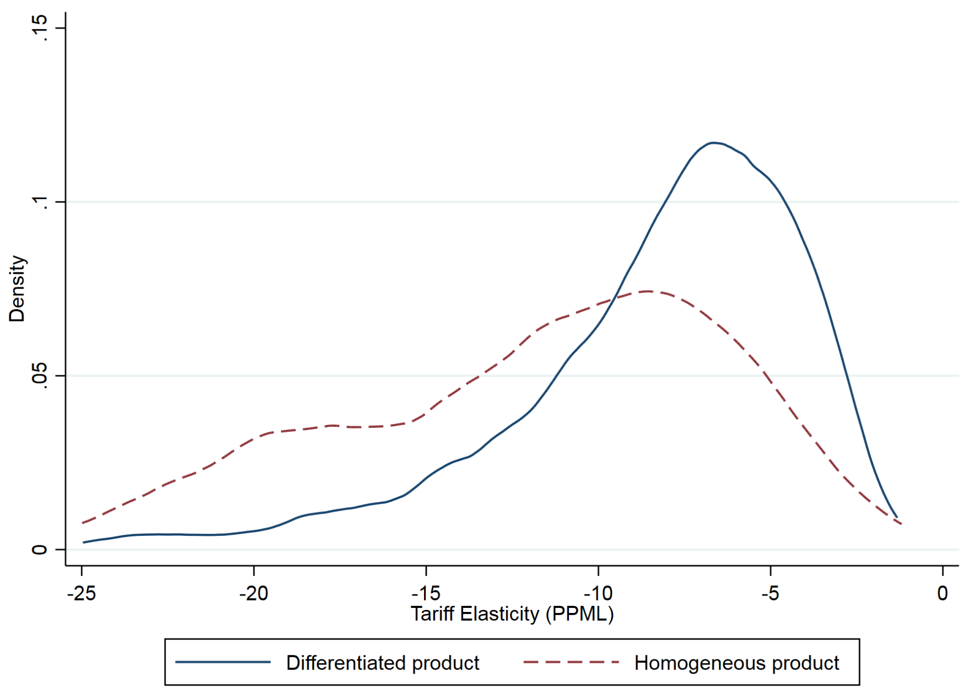
Source: Authors' calculations. Note: empirical distribution calculated on negative tariff elasticities. Positive and non-significant tariff elasticities not considered.

Figure A2: Empirical distribution of tariff elasticity. Manufacturing vs. Agriculture sectors



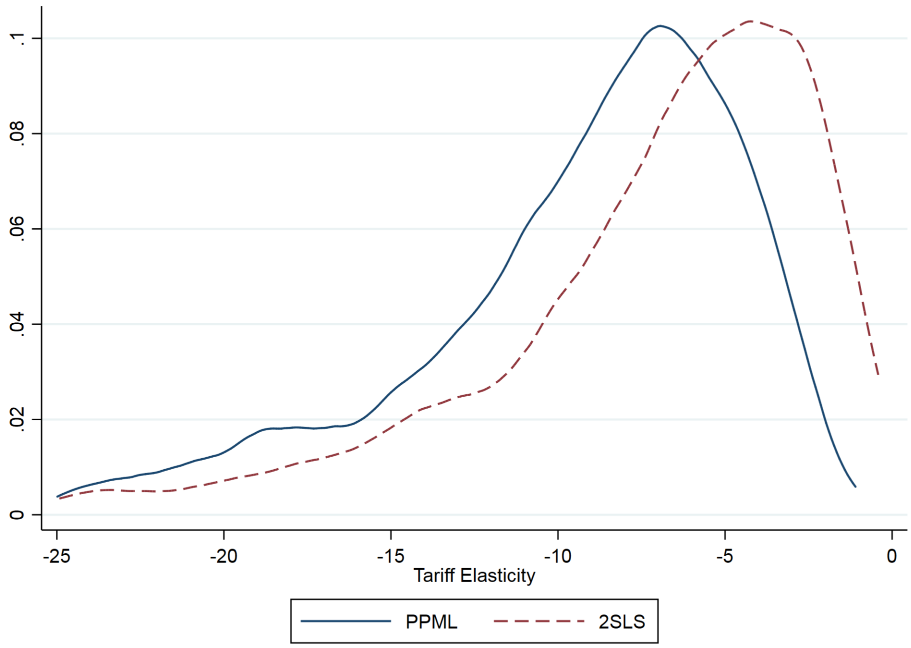
Source: Authors' calculations. Note: empirical distribution calculated on negative tariff elasticities. Positive and non-significant tariff elasticities not considered.

Figure A3: Empirical distribution of tariff elasticity. Homogeneous vs Differentiated products (based on Rauch classification).



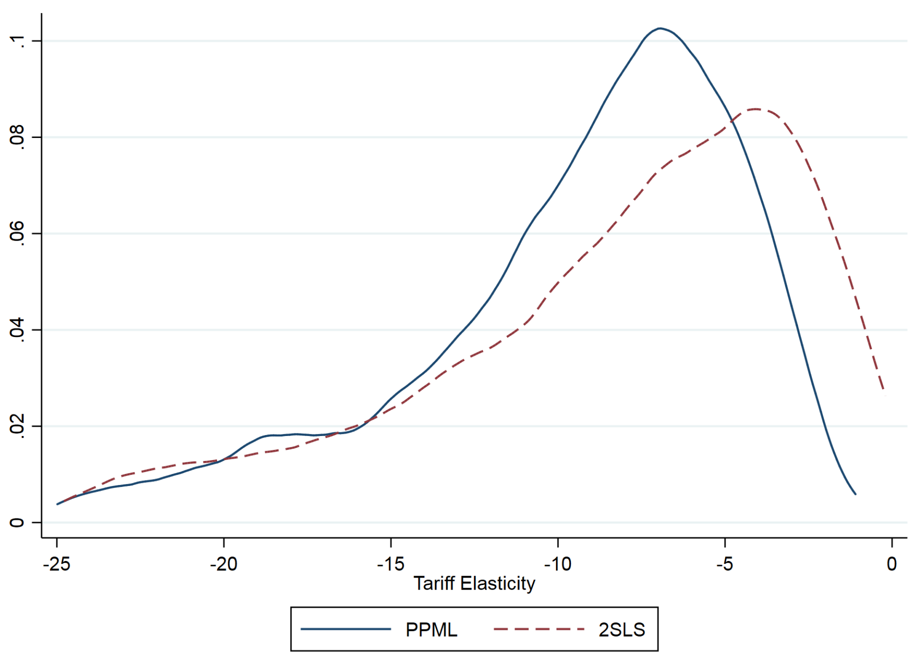
Source: Authors' calculations. Note: empirical distribution calculated on negative tariff elasticities. Positive and non-significant tariff elasticities not considered.

Figure A4: Empirical distribution of tariff elasticity. PPML vs 2SLS estimations. IV based on macro-region averages



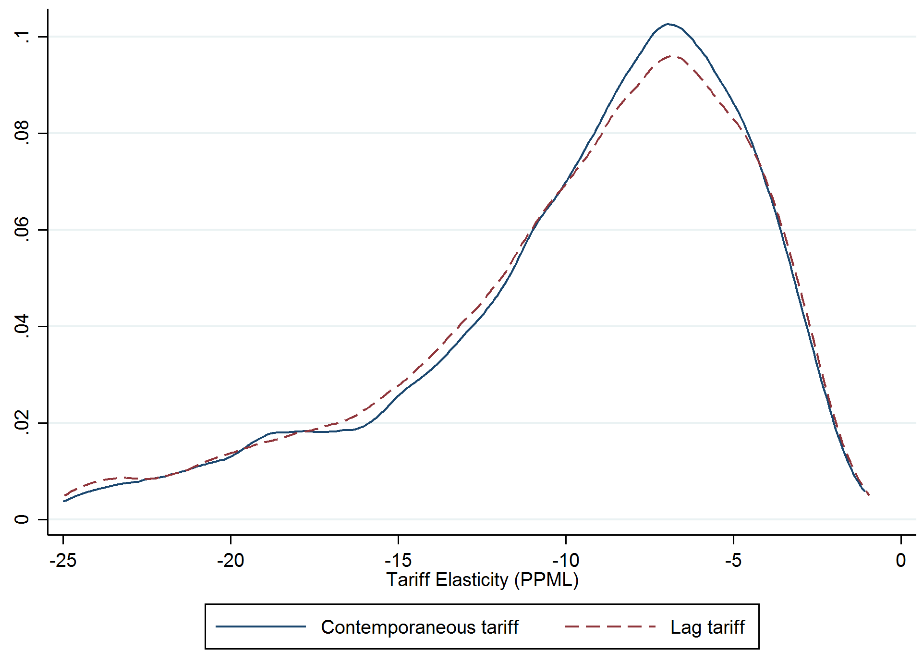
Source: Authors' calculations. Note: empirical distribution calculated on negative tariff elasticities. Positive and non-significant tariff elasticities not considered.

Figure A5: Empirical distribution of tariff elasticity. PPML vs 2SLS estimations. IV based on MAcMap-HS6 reference group averages



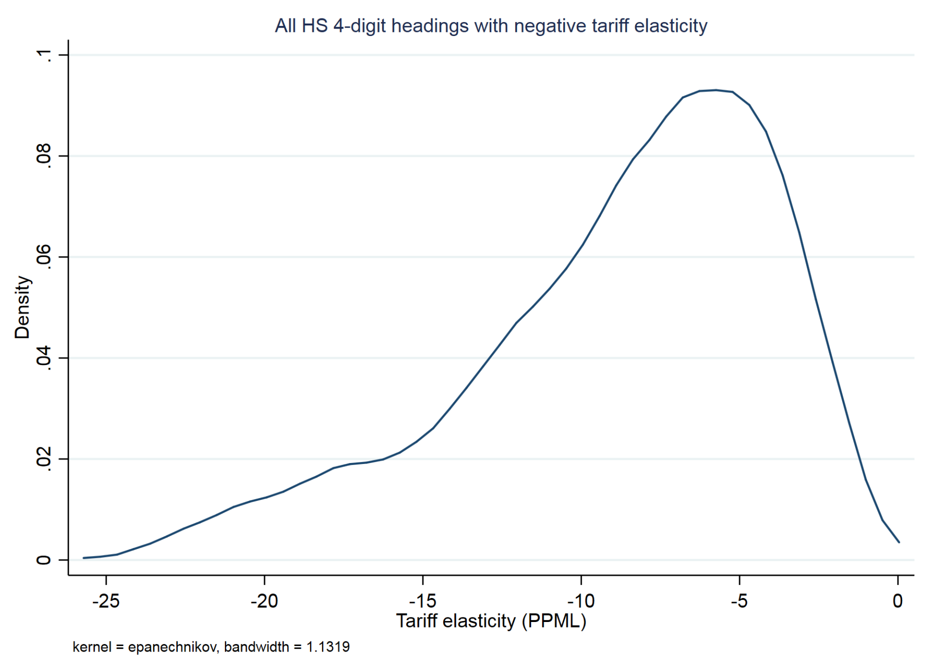
Source: Authors' calculations. Note: empirical distribution calculated on negative tariff elasticities. Positive and non-significant tariff elasticities not considered.

Figure A6: Empirical distribution of tariff elasticity. Contemporaneous vs lag tariff estimations.



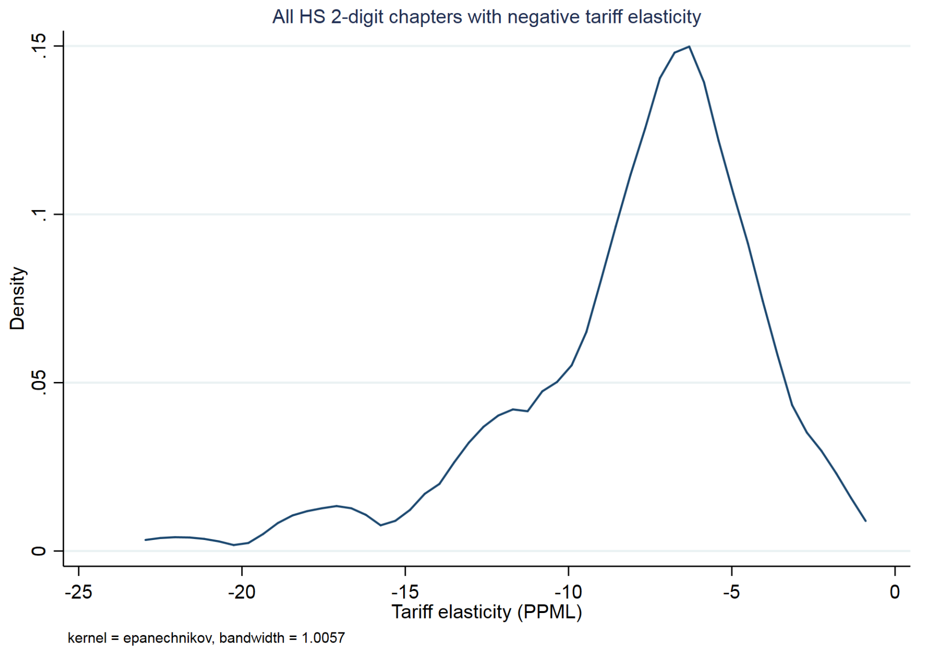
Source: Authors' calculations. Note: empirical distribution calculated on negative tariff elasticities. Positive and non-significant tariff elasticities not considered.

Figure A7: Empirical distribution of tariff elasticity across all sectors estimated by HS 4-digit heading



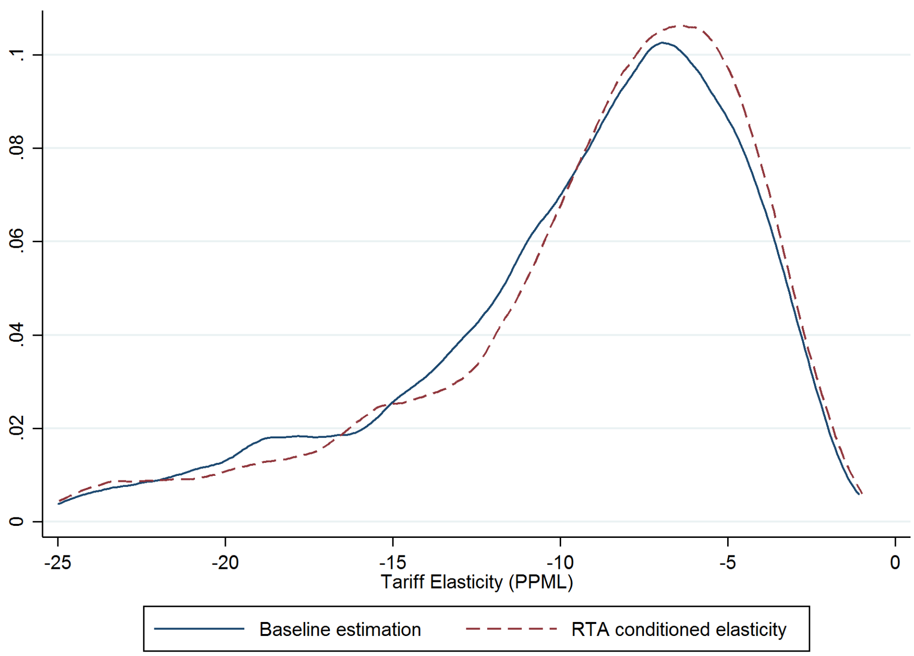
Source: Authors' calculations. Note: empirical distribution calculated on negative tariff elasticities. Positive and non-significant tariff elasticities not considered.

Figure A8: Empirical distribution of tariff elasticity across all sectors estimated by HS 2-digit chapter



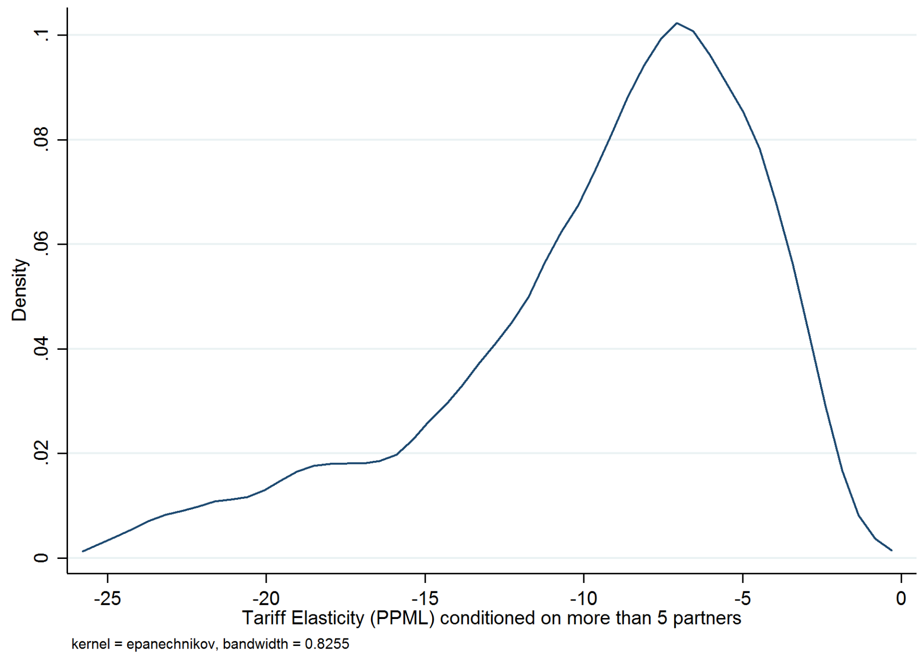
Source: Authors' calculations. Note: empirical distribution calculated on negative tariff elasticities. Positive and non-significant tariff elasticities not considered.

Figure A9: Empirical distribution of tariff elasticity: (i) baseline, and (ii) conditioned on RTA dummy.



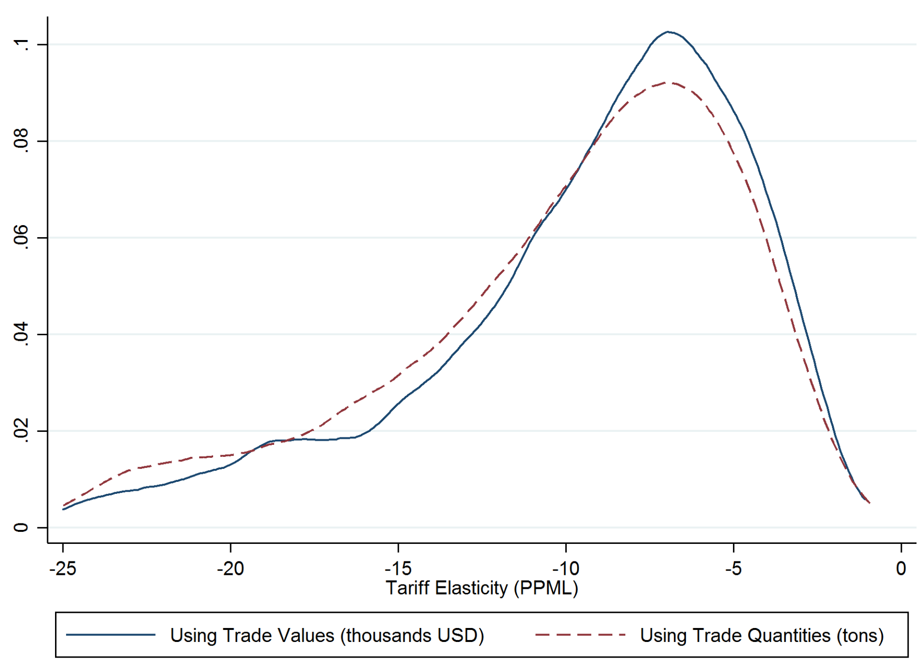
Source: Authors' calculations. Note: empirical distribution calculated on negative tariff elasticities. Positive and non-significant tariff elasticities not considered.

Figure A10: Empirical distribution of tariff elasticity conditioned on having more that five trade partners.



Source: Authors' calculations. Note: empirical distribution calculated on negative tariff elasticities. Positive and non-significant tariff elasticities not considered.

Figure A11: Empirical distribution of tariff elasticity estimated on trade volumes (Kg)



Source: Authors' calculations. Note: empirical distribution calculated on negative tariff elasticities. Positive and non-significant tariff elasticities not considered.