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Estimating Foreign and National Trade Elasticities in the EU Internal Market Using Generalized Transport Costs

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Abstract

This paper undertakes the simultaneous estimation of import elasticities of substitution (trade elasticities) within European Union (EU) regions, differentiating between imports from regions belonging to the same country (national or interregional trade) and regions belonging to other EU countries (international trade within the EU). We use a nested CES utility structure to derive the corresponding trade gravity equations and estimate them by way of Poisson pseudo-maximum likelihood regression. As the EU is a single market, the usual approach followed in the international trade literature that relies on changes in bilateral tariffs cannot be used to identify the trade elasticities. To address this issue, a very detailed definition and calculation of the ad valorem specification of transport costs is performed. The methodology takes into account the transport engineering and logistic characteristics of road freight transportation, which allows us to obtain a reliable measure of the generalized transport costs between regions. Trade elasticities are calculated at several levels of industrial aggregation, including individual sectors at 2-digit CPA classification, and their higher-level categories corresponding to agriculture, mining, and manufacturing. Results show that the trade elasticity increases the closer are the trading partners; i.e., national vs. foreign elasticities, thereby providing the first evidence of this widely presumed hypothesis. National trade elasticities are broadly double the value of their foreign counterparts. We also find that trade elasticities substantially decrease as commodities are considered at a higher level of aggregation. Our calculated trade elasticities can be adopted in a wide array of models of international trade, or spatial economic models such as Regional Computable General Equilibrium models (e.g. the RHOMOLO model), improving the results obtained from simulations aimed at policy analysis.

JEL Classification: C21, C68, F12, F17, R41

Keywords: Gravity equation, trade elasticities, interregional trade, international trade, generalized transport costs.

1. Introduction

Elasticities of import substitution play a key role in modern trade theory by capturing the sensitivity of consumers' relative demand for domestic and foreign goods to changes in their relative prices (Hillberry and Hummels, 2013). Under the usual assumption of constant elasticity of substitution (CES) between goods in the utility function, the elasticity between any two varieties produced in different foreign locations corresponds to the elasticity of import substitution (hereafter, trade elasticities); i.e., the inverse of the cross-price elasticity of demand between foreign goods (Feenstra, 2016). Once embedded in a Computable General Equilibrium (CGE) framework, these elasticities shape market dynamics of the output and input markets in response to shocks. The ripple effects of changes in trade costs (through for example infrastructure investments or changes in tariffs) are particularly relevant in open economies like those belonging to free trade areas or, as in the case of the EU, single markets (Blonigen and Wilson, 2018). For example, trade liberalization brings about relevant modifications in the structure of the output and inputs markets, and the location of economic activity both between and within countries (Gallego and Zofío, 2018). In the markets for goods they tend to disrupt the status quo by altering the degree of competition through changes in the size of firms, generally reinforced with selection effects (Burstein and Melitz, 2013). Changes in trade costs can have significant effects on the labor market, with longer response times as a result of rigidities and frictions. This multiplicity of interrelated effects across the economies can only be captured within a general equilibrium setting, and CGE models become key for policy analyses and evaluations.

The central role played by the trade elasticities explains the interest in obtaining reliable estimates for the calibration of CGE models. Major trade-focused CGE models draw elasticities from a wide range of studies. These econometric studies follow alternative specifications (e.g., gravity equations, demand and supply systems), estimation methods (e.g., GMM, ordinary least squares, Poisson pseudo maximum likelihood,...), sample data (cross-section or panel) specific to geographic locations and time (e.g., world regions, particular free trade areas,…), etc. This translates into numerous results and the modeler's question is what the best elasticities for the model at hand are. Although one can always find a relatively close match between the needs of CGE models and the available econometric results, there is an area in which there has not been much headway. Specifically, for regional CGEs, there exist few studies on trade elasticities between regions belonging to the same country, or, if data is available as in our case, between regions belonging to several countries.

The main contribution of this report is the introduction of a framework for the joint estimation of interregional (intra-national) and international (foreign) trade elasticities for single market areas for which both trade data and transport cost data are available. To the best of our knowledge, this is the first time that such simultaneous estimation has been proposed and performed. Indeed, most of the studies surveyed in literature reviews (e.g., Francois and Martin, 2013; Hillberry and Hummels, 2013) refer to international CGE modelling, where trade takes place between countries and there is a single trade elasticity parameter capturing the relationship between either domestic and foreign goods or between goods sourced from different countries (foreign-foreign). There are, however, a handful of CGE models for single countries, where regions trade with each other, e.g., as those for the US surveyed by Bilgic et al. (2002). In these models, the transport related costs play a leading role in the identification and quantification of interregional trade elasticities since changes in the relative import price indices are not driven by shocks to tariffs or any other non-transport related cost. Hence, to estimate trade elasticities within countries, ones needs to rely on intra-national (i.e., interregional) trade flows and the existing (non-linear) relationship with actual transportation costs (Hillberry and Hummels, 2008, Díaz-Lanchas et al., 2019).[2] Arguably, the estimation of trade elasticities is more challenging for single market CGE models than for their internationally oriented counterparts, since the difference between domestic and imported goods is conceptually blurry, and the elasticities cannot be identified by considering the effect of tariffs on trade flows—*à la* Hertel et al. (2007).

Whether the model includes countries or regions only, or both, is key to the interpretation, identification and numerical determination of trade elasticities.[3] In models consisting only of countries that do not belong to a single-market, the trade costs of interest from a modeling perspective are tariffs, whose level is customarily changed to assess the effects of policies aiming at increasing or reducing trade liberalization. Transport related costs are of secondary importance and can be fairly regarded as control variables, whose measurement does not require extraordinary detail or complexity, and therefore may be adequately represented by average freight rates between countries, or even simple geographic distance. This is however not the case for regional CGEs oriented towards a lower level of spatial disaggregation, usually characterized by single markets and where tariffs have been removed. These models situate between international models with many countries (e.g., Global Trade Analysis Project, GTAP) and single country models (e.g., US International Trade Commission, USAGE). Central to our study, a representative example of this type of models is the RHOMOLO model for the European Union (EU).[4] This model draws from previous experiences of regional EU CGE modelling (e.g., Bröker, 2015), and is

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[2] We note that this bypasses one of the problems identified by Hillberry and Hummels (2013) related to the correlation between non-transport related costs such as tariffs and the error term in the gravity equation, i.e., political economy suggests that tariffs are higher under the threat of potential import substitution.

[3] Using a trade gravity equation, the value of the trade elasticities can be estimated using the coefficients associated to trade costs (i.e., the source of price variation among varieties). Transport costs are typically expressed on a multiplicative (i.e., iceberg or ad valorem), or an additive (i.e., per unit) basis (see, e.g., Irarrazabal et al., 2015). In the multiplicative case price at destination including all transport costs equals the price in origin *times* the proportion (τ) corresponding to trade costs, $p(1+\tau)$, $\tau \geq 0$, while in the additive case it is equal to the price in origin *plus* transport costs, $p + t$, $t \geq 0$ (hence, independent of the price in origin). Although it is obvious that the iceberg or ad valorem definitions can be set to match any observed value of transport costs, the functional form starts to matter when the price changes. Imagine that a production tax or an increase in quality leads to higher prices of some tradable goods, then, under the assumption of multiplicative transport costs, they increase proportionally (except perhaps for the insurance premiums). An effect that would most likely be unintended and not realistic. In CGE models the latter definition is nevertheless standard practice.

[4] https://ec.europa.eu/jrc/en/rhomolo.

maintained by the REMO modelling team of the Joint Research Center of the European Commission. The current—third—version of the model features the most relevant and latest advances in regional modelling and trade theory (e.g., competitive and imperfectly competitive markets, alternative labor market closures allowing for rigidities and frictions in the wage curve, etc.)—see Lecca et al. (2018). It is arguably the largest and most sophisticated model in terms of its spatial dimension by covering a total of 267 NUTS-2 regions within 28 countries, disaggregating their economies into ten 2-digit NACE rev. 2 sectors.

Consistent with the theoretical features of this model, the most salient contribution of this report is that, by taking advantage of data on regional trade flows both between and within countries (i.e., international and intranational trade), we can estimate two levels of import elasticities of substitution. Considering the customary Armington assumption that buyers in a region treat varieties as differentiated on the basis of the location of origin we distinguish and calculate, on the one hand, the elasticity of substitution between domestic goods produced within the region and those imported from abroad, and originating in different regions located in *foreign* EU countries—as in the existing studies for international trade. On the other hand, we exploit the information on trade between a given region and other regions *within* the same country to estimate a second *national* elasticity of substitution for imports, which are supposed to be closer in the product space given that they share similar idiosyncratic characteristics and are better known to consumers.[5] On these grounds, it is hypothesized that for the EU, international trade elasticities (i.e., between regions in different countries) represent lower bounds for regional trade elasticities (i.e., between regions in the same countries), see e.g., Bilgic et al. (2002). Our results confirm this hypothesis, concluding that the closer the geographical reach of trade, i.e., regional versus international trade, the higher the substitutability between varieties from different origins.

We compare the results obtained with previous estimates of trade elasticities at both the country and regional level. Most of the elasticities based on the Armington assumption refer to the US and very few to Europe. At the country level, and for the European case, there are some recent econometric estimates by Németh et al. (2011), Olekseyuk and Schürenberg-Frosch (2016) and Aspalter (2016). The range of elasticities in each of these studies go from around 2 to 5, in the interval of 3 and 4.2, and 0.3 and 3.7, respectively. These elasticities are consistent with other studies where single European countries (i.e., foreign elasticities) are considered (Welsch, 2008; Imbs and Méjean, 2010, 2015). Also, some of these studies not only reveal that trade elasticities exhibit a great deal of heterogeneity between countries, but also depending on the level of industrial aggregation;

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[5] In the literature, there is the distinction between home-foreign substitution and foreign-foreign substitution, where the former is obtained from time-series data referring to the same imports flows observed across-time, and the latter would be obtained from cross-sectional data as in the present study (see, e.g., Németh et al., 2011). Moreover, when cross-section estimates for CGE multicountry modeling were unavailable the "rule of two", by which foreign-foreign substitution was twice the values of the home-foreign elasticity of substitution, was generally applied, Hillberry and Hummels (2013; 1,228). Our empirical results provide evidence in favor of this rule.

i.e., as would be the case when moving upwards in the digit classification by successively increasing the aggregation of trade flows (e.g., from a two to a single-digit classification). Due to its relevance for CGE modelling, where either just a single or few (highly aggregated) elasticities are considered, we also explore this question empirically by estimating trade elasticities by different levels of industrial aggregation, finding consistent evidence that, indeed, aggregating upwards decreases their value.

Key to the estimation of trade elasticities is a very detailed matrix of transport costs. Rather than using proxies like distance, the definition of trade costs follows a generalized transport cost (GTC) approach, which calculates the minimum cost of shipping freight between any two locations along the least expensive route. Given the percentage of freight transportation in the EU by road (over 85%), and the impossibility of setting an EU wide intermodal freight transportation model due to the lack of reliable statistics, we focus on the road transportation mode.[6] The methodology takes into account the economic costs of transportation, and where the choice of the optimal vehicle size depends on: a) 'freight curves', balancing fixed costs such as terminal times (handling costs) and variable costs (hauling costs) (McCann, 2001); b) the urban layout of the origin and destination in terms of population density, and c) the type of commodity (cargo) transported. Here the transport engineering and logistics approach presented by Zofío et al. (2014) is enhanced to account for the existence of non-linear shipping costs resulting from economies of distance and size. The aim is to reduce to a minimum the likely correlation between transport related costs and the error term in the gravity equation, by making sure that the ad-valorem transportation costs control for all these specificities. This information is then embedded in a geographical information system (GIS) representing the digitalized transportation network across the EU. Following Persyn et al. (2020), the optimal route associated with the minimum cost is calculated using Dijkstra (1959) algorithm. In a computationally intensive process, a sample of centroids based on nighttime satellite imaging at a one squared km resolution is considered for every pair of regions to take into account the typically uneven distribution of economic activities within the regions. Subsequently, the set of bilateral GTCs between any two regions is aggregated through the arithmetic mean.[7] In the last step, averaged GTCs (by sector and type of vehicle) are employed to calculate the ad valorem cost of transporting the observed trade between any two regions, which is the variable that is used in the estimation of the gravity equation.

The gravity equation introduced in this report is consistent with the theoretical model that follows the RHOMOLO framework, but whose characteristics, beyond EU specificities, are nevertheless common to other regional CGEs models. Although the underlying assumptions could be easily changed, as the estimated trade elasticities will enter the set of parameters needed to calibrate the model, we rather maintain the basic framework. This should result in more reliable simulations exercises upon which regional policy analyses are

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[6] Since 1999 non-road transportation modes, mainly train and inland waterways, has stalled. Mostly due to a low containerization rate, deterioration in the quality of services of intermodal transport, and improvements in the efficiency and quality of road transport services, Janic (2007).

[7] It is possible also to consider the harmonic or weighted mean, capturing the location of economic activity, as argued by Head and Mayer (2009).

based—see Di Comite et al. (2017)—for different policy impact assessment within a New Economic Geography framework. This means that household and firm behavior follow standard specifications. However, the representative consumer maximizes a three-tier utility function (rather than the usual two) which allows the characterization of the foreign and national trade elasticities, and where the middle and lower tier are characterized by an asymmetric CES utility presenting constant substitutability among varieties. As for markets, these are characterized by either constant or increasing returns, resulting in perfect and imperfect competition, and where the market structure in the latter case is assumed to be that of monopolistic competition, thereby doing away with strategic behavior among firms.

The report is structured as follows. In the next section we present the theoretical model underlying the specification of the gravity equation. Here we derive the demand equations for domestic goods, nationally (interregional) imported goods within the same country, and internationally imported goods from regions located in foreign countries. Next, in the third section, we discuss the specific econometric specification of the gravity equations and the estimation strategies. In the fourth section we discuss the data related to trade flows, generalized and iceberg transport costs, and ancillary control variables. Here we introduce the methodology employed to calculate the ad valorem trade costs based on the generalized transport costs that take into consideration the choice of optimal vehicle size depending on three factors: the distance between the origin and destination location, their relative degree of urbanization and the nature of the commodity transported. In section five we present our estimates of the trade elasticities differentiating between national and international substitutability, as well as the level of industrial (sectoral) aggregation. Finally, we conclude by stressing novelty of the results and their relevance for regional CGE modelling.

2. The model: A gravity specification for national and foreign trade elasticities

The theoretical model from which we derive the import demand equations underlying the gravity equation for non-domestic goods is consistent with the regional CGE RHOMOLO model. Household preferences are modelled as a triple nested utility function. The upper tier utility for the representative consumer in a region *d* corresponds to

$$U_d = (Q_d^1, \dots, Q_d^c, \dots, Q_d^C), \tag{1}$$

which aggregates the $c = 1,\dots,C$ quantities of commodities demanded (normally aggregated into sectors based on their similarity in the product space as done in international classifications; e.g., agriculture, manufacturing, services,…), and whose functional form may range from the simplest Cobb-Douglas formulation, the Constant Elasticity of Substitution (CES), the quasi-linear or quadratic specifications, to more complex non-homothetic characterizations if income effects are of interest (Fieler, 2011).

For open sectors, the amount consumed is a composite of horizontally differentiated varieties of the same good that may be produced domestically in the region *d* itself or imported either from regions from within the same country (*national* consumption), or from regions situated in foreign countries (*foreign* consumption). With this structure in mind, the middle tier of the utility function is expressed by way of the following CES specification:[8]

$$Q_d^c = \left[b_{Nd}^c Q_{Nd}^{c\;\frac{\phi^c-1}{\phi^c}} + b_{Fd}^c Q_{Fd}^{c\;\frac{\phi^c-1}{\phi^c}} \right]^{\frac{\phi^c}{\phi^c-1}}, \tag{2}$$

In this function a further distinction is made by differentiating between intranational and international trade, and, therefore, Q_d^c is the result of aggregating the varieties imported from regions within the same nation (*N*), Q_{Nd}^c, and those imported from foreign regions located in other countries (*F*), Q_{Fd}^c. In (2), the parameters b_{Nd}^c and b_{Fd}^c represent preference weights specific to each source; i.e., nationally imported and internationally imported. The parameter $\phi_c > 1$ is the elasticity of substitution among these alternative sources of good *c* in region *d.* We assume that this elasticity is equal across the European Union importing regions, *d* = 1,…,*D*.

Finally, in the lower tier, and indexing by *n*=1,…,*N* and *f*=1,…,*F* the exporting regions belonging to the same country of the importer and those situated abroad, respectively, the composite demands for individual goods having a national or foreign origin are represented by their corresponding CES utility functions:

$$Q_{Nd}^c = \left[\sum_{n=1}^{N} b_{nd}^c q_{nd}^{c\;\frac{\sigma_N^c-1}{\sigma_N^c}} \right]^{\frac{\sigma_N^c}{\sigma_N^c-1}}, \tag{3}$$

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[8] A similar framework has been proposed by Feenstra et al. (2014) to identify the elasticity of substitution between domestic and foreign goods (i.e., considering imports as a whole aggregate over foreign countries), and differentiate it from goods imported from different countries. These authors refer to the former and the latter as macro and micro elasticities of substitution. Our approach differs from theirs because, having a regional scope, we differentiate between the elasticity of substitution between domestic and goods imported from regions within the same country (giving rise to national or interregional trade), and regions located in foreign countries. That is, we distinguish between domestic producers and other national suppliers, and between domestic producers and foreign suppliers. Feenstra et al.'s approach, recently published as Feenstra et al. (2018), was adopted by Aspelter (2016), who estimates the macro and micro elasticities of substitution for 15 EU member states. In passing, we note that the denomination of micro and macro elasticities is somehow unfortunate, because in the trade literature these terms are also used to differentiate elasticity estimates for different (lower and higher) levels of aggregation of trade data, as we do in this study (e.g., alternative industry groups representing different levels of aggregation).

$$Q^c_{Fd} = \left[\sum_{f=1}^{F} b^c_{fd} {q^c_{fd}}^{\frac{\sigma^c_F - 1}{\sigma^c_F}} \right]^{\frac{\sigma^c_F}{\sigma_F - 1}}, \tag{4}$$

where q^c_{nd} and q^c_{fd} are the quantity of sector *c* commodity consumed in *d* imported from regions *n* in the same country, and from regions *f* in other countries, respectively. In this level b^c_{nd} and b^c_{fd} are the preference parameters for each of the varieties imported from the national or foreign regions, and σ_N and σ_F are the common associated elasticities of substitution among varieties sourced from each group of regions. Once again, we assume that these elasticities are equal across the importing regions.

We now determine the aggregate demand for the national and foreign imported goods of the representative consumer maximizing (2) conditional on the expenditure on each type of commodity depending on its *origin*, $E^c_{od}, o = N, F$ (coming from the upper level utility function (1)), and assuming that the relevant market structure corresponds to monopolistic competition.[9] In this case the optimal sourcing of imports from different importers, *n* or *f*, according to (3) and (4), results in the following demand equations:

$$q^c_{nd} = {b^c_{nd}}^{\sigma^c_N} \frac{{p^c_{nd}}^{-\sigma^c_N}}{{P^c_{Nd}}^{1-\sigma^c_N}} E^c_{Nd}, \text{ and} \tag{5}$$

$$q^c_{fd} = {b^c_{fd}}^{\sigma^c_F} \frac{{p^c_{fd}}^{-\sigma^c_F}}{{P^c_{Fd}}^{1-\sigma^c_F}} E^c_{Fd}. \tag{6}$$

In these commodity specific demands, destination prices in the numerator correspond to the following specifications:

$$p^c_{nd} = p^c_n(1 + \tau^c_{nd}) = \left(\frac{\sigma^c_N}{\sigma^c_N - 1}\right) c^c_n(1 + \tau^c_{nd}), \text{ and} \tag{7}$$

$$p^c_{fd} = p^c_f(1 + \tau^c_{fd}) = \left(\frac{\sigma^c_F}{\sigma^c_F - 1}\right) c^c_f(1 + \tau^c_{fd}). \tag{8}$$

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[9] In the RHOMOLO model sectors are assumed to be either perfectly competitive or characterized by monopolistic competition—see Lecca (2018: 11). In particular, following the NACE Rev. 2 presented in Appendix 1, tradable goods correspond to the two-digit codes A, B, and C. Agriculture (A) is the sector normally treated as perfectly competitive in trade models, while the rest of industries represent imperfectly competitive sectors. Since the final econometric specification that allows the identification of the trade elasticities associated to the trade costs does not differ between the two, we show the general case corresponding to monopolistic competition. I.e., the equilibrium condition under perfect competition corresponds to the simplest case where marginal revenue equals price, and therefore the profit maximizing condition for the firms requires that prices equal marginal cost. It is possible to show that solving the model under this condition, i.e., obtaining the counterparts to eqs. (5) and (6), yields the same gravity equation.

In these expressions $p_n^c = \left(\frac{\sigma_N^c}{\sigma_N^c-1}\right) c_n^c$ and $p_f^c = \left(\frac{\sigma_F^c}{\sigma_F^c-1}\right) c_f^c$ are mill prices in the origin region, which depend on the marginal cost of production c_o^c, o = n, f (e.g., labor requirements in terms of salary, energy prices, etc.);[10] and $\sigma_N/(\sigma_N - 1)$, and $\sigma_F/(\sigma_F - 1)$ are the mark-ups reflecting the degree of market power under monopolistic competition. The consumer prices p_{nd}^c and p_{fd}^c at the destination region *d* furthermore depends on τ_{nd}^c and τ_{fd}^c, the *ad valorem* (or iceberg) transport costs between the exporting and importing region;

Finally, the overall price indices over the imported commodities are:

$P_{Nd}^c = \left(\sum_{n=1}^N {b_{nd}^c}^{\sigma_N} (p_{nd}^c)^{1-\sigma_N}\right)^{1/1-\sigma_N}$, and

$P_{Fd}^c = \left(\sum_{f=1}^F {b_{fd}^c}^{\sigma_F} (p_{fd}^c)^{1-\sigma_F}\right)^{1/1-\sigma_F}$.

3. Econometric specification and estimation of trade elasticities.

We express the demand equations (5) and (6) in value terms by multiplying both sides by destination prices. Also in a monopolistic competition framework the aggregate import value can be related to the individual firm *h* exports multiplied by the number of symmetric firms *m* operating in the exporting industry; i.e., $V_{od}^c = p_{od}^c m_o^c q_{hod}^c = p_{od}^c q_{od}^c, o = n, f$.[11] Then, multiplying (5) by (7) as presented in the second equality, and taking natural logs of the resulting equation, yields the following gravity equation for (intra)national trade:[12]

$$\ln V_{nd}^c = \sigma_N^c \ln b_{nd}^c + \ln m_n^c + (1 - \sigma_N^c) \ln\left(\frac{\sigma_N^c}{\sigma_N^c - 1}\right) + (1 - \sigma_N^c) \ln(c_n^c) \\ + (1 - \sigma_N^c) \ln(1 + \tau_{nd}^c) + (\sigma_N^c - 1) \ln P_{Nd}^c + \ln E_{Nd}^c.$$

In the same vein, multiplying (6) by (8), one obtains the gravity equation for international trade:

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[10] Note that there is a single mill (factory gate) price in each exporting region, and therefore it is assumed that they do not undertake price-discrimination depending on the region of destination. This is consistent with EU competition law, banning this discriminatory practice. The legal definition of price discrimination in Article 102 (TFEU) refers to the application of "*dissimilar conditions to equivalent transactions with other trading parties, thereby placing them at a competitive disadvantage*". In international trade agreements this corresponds to the most favored nation clause.

[11] We assume that all firms within a given region operate with the same technology and face the same input costs. Consequently, for simplicity, we drop the firm specific subscript *h* in the following expressions.

[12] In the final econometric specifications of the gravity equations shown below the number of firms or varieties, along with the preference parameters, and any origin-specific determinants are eventually swept out by the fixed effects capturing export-only characteristics. Correspondingly, the importer region's price index, expenditure, and any other destination-specific determinants are also swept out by the importers' fixed effects.

$$\ln V_{fd}^{c} = \sigma_F^c \ln b_{fd}^c + \ln m_f^c + (1-\sigma_F^c)\ln\left(\frac{\sigma_F^c}{\sigma_F^c - 1}\right) + (1-\sigma_F^c)\ln\left(c_f^c\right)$$
$$+ (1-\sigma_F^c)\ln(1+\tau_{fd}^c) + (\sigma_F^c - 1)\ln P_{Fd}^c + \ln E_{Fd}^c.$$

The econometric identification of the elasticities of import substitution relies on the cross-sectional variation of delivered prices induced by trade costs. In our single market setting characterizing the EU, delivered prices corresponds to mill prices plus the trade margins, of which ad valorem transport costs represent the largest proportion, and excluding non-transport related costs since there are no additional trade barriers such as tariffs.[13]

3.1. (Intra)national and foreign (international) trade elasticities by sector

The above specifications can be estimated separately for each type of trade flow (either national or foreign) and sector *c*. The standard econometric strategy followed by authors like Hummels (2001) and Hertel *et al.* (2007) exploits the fact that all variables except the bilateral preferences and transportation costs: b_{od}^c , $\tau_{od}^c, o = n, f$, are either importer or exporter specific, and therefore their effects on bilateral trade can be captured through importer and exporter specific fixed coefficients. Denoting by a_d^c and a_n^c the vectors of importer and exporter (within the same country) regional fixed effects, results in the following specification:

$$\ln V_{nd}^c = a_d^c + a_n^c + \sigma_N^c \ln b_{nd}^c + (1-\sigma_N^c)\ln(1+\tau_{nd}^c), c=1,\ldots,C. \quad (9)$$

while the international counterpart, including exporter's fixed effect for foreign countries a_f^c , corresponds to:

$$\ln V_{fd}^c = a_d^c + a_f^c + \sigma_F^c \ln b_{fd}^c + (1-\sigma_F^c)\ln(1+\tau_{fd}^c), c=1,\ldots,C. \quad (10)$$

Unobservable characteristics such as quality and other commodity characteristics are the same in each destination to which an exporter $o\ (= n, f)$ sells to, and can therefore be captured by the fixed effects. The commodity-specific preference parameters b_{od}^c captures other idiosyncratic characteristics such as taste that may affect trade between the importer and exporter. It is customary to include distance and adjacency (contiguity) as proxies for this variable: $b_{od}^c = b_o^c Dist._{od}^{\delta_1^c} e^{\delta_2^c Adj.}$.

Rather than estimating the sector specific elasticities of trade for national and foreign goods separately, i.e., using split subsamples corresponding to each type of trade flow, our estimation strategy pools all data. This implies that a single specification of the gravity

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[13] The difference between (export) FOB and (import) CIF definitions of trade flows, with the latter including not only transport costs, but also insurance and taxes, becomes relevant when compiling the data for the empirical estimations. This is discussed in section 4.1 below.

equation can be implemented in such a way that σ_N^c and σ_F^c can be recovered simultaneously from the estimated parameters. This is achieved by defining a specification that allows for both levels of trade flows, i.e., regressing all trade flows on $\tau_{od}^c, o = n, f$, and their corresponding bilateral variables, but subsequently qualifies this overall value by introducing a dummy that controls for national trade. The associated parameter effectively captures the additional (marginal) effect on imports if trade is (intra)national rather than international (i.e., the reference category). Considering this estimation strategy results in the following specification:

$$\begin{aligned}\ln V_{od}^c = {} & \alpha_0 + \alpha_d^c + \alpha_o^c + \beta_f^c \ln(1+\tau_{od}^c) + \beta_n^c \ln(1+\tau_{od}^c) \times Bord.country_{od} + \beta_1^c \ln Dist._{od} \\ & + \beta_2^c\, Bord.region_{od} + \beta_3^c\, Bord.country_{od} + \beta_4^c\, Adj.region_{od} + \beta_5^c\, Adj.country_{od} \\ & + \varepsilon_{od}, \;\; o = n, f, \;\; c = 1, \dots, C.\end{aligned} \tag{11}$$

Here α_d^c and α_o^c are the importing and exporting region specific fixed effects; $Bord.region_{od}$ and $Bord.country_{od}$ are dummy variables which equal one if the trade flow takes place within the same region and country respectively; while $Adj.region_{od}$ and $Adj.country_{od}$ are dummy variables indicating if the flow takes place between adjacent regions within the same country or between adjacent regions of different countries. Distance is included as a proxy for the bilateral taste parameter, but the presence of this variable also implies that the identification of the elasticity parameter will solely depend on how trade flows react to differences in trade costs that are not driven by distance.

As explained in the following section, the iceberg transport cost included in the estimation relies on a precise measure of generalized transport costs at the sectoral level for each origin-destination pair, $GTC_{od}^c,\ o = n, f$. This measure, constituting the second novelty of this report, overcomes the simplicity of the geographical distance, common to all sectors, by considering aspects such as the road transportation network, urban morphology and population density, economic costs of the optimal sector specific vehicle (depending on the cargo), etc. Therefore, our ad valorem (iceberg) measure of transport cost, $\tau_{od}^c,\ o = n, f$, depends on all these dimensions, as well as freight data in tons and value. Again, by controlling for the basic distance measure in addition to transport costs, we ensure that the elasticity parameters reflect spatial differences in this entire array of infrastructure, technological, logistic and economic variables affecting trade.

The foreign and national elasticities of trade can be identified from the parameters associated with the bilateral variation in transportation costs: i.e., $\sigma_F^c = 1 - \beta_f^c$ and $\sigma_N^c = 1 - (\beta_f^c + \beta_n^c)$. In the results section, where we present the values of the trade elasticities according to expression (11), we test whether they are both different from one and from each other. In addition, both the individual and joint statistical significance of these parameters is crucial. From an econometric perspective, an additional advantage of relying on a joint specification such as (11), with respect to the alternative individual regressions for both elasticities based on (9) and (10), is the possibility of testing whether the gap between the national and foreign trade elasticities is statistically significant or not.

As for the estimation method, we follow Santos Silva and Tenreyro (2006, 2010, 2015) and Francois and Martin (2013) and use Poisson Pseudo Maximum Likelihood (PPML).[14] The Poisson estimator is consistent and unbiased in the presence of heteroscedasticity when the data have a large number of zeros. Additionally, it yields more efficient estimators than the OLS counterparts. Additionally, this method identifies and eventually drops regressors that may cause the non-existence of the (pseudo) maximum likelihood estimates, presenting several advantages given the problems posed by the existence of numerous zeros and use of dummy variables (see also Head and Mayer, 2014).

3.2. Pooling (intra)national and foreign (international) trade data by sector

As it is standard practice in the literature, the above regressions yield estimates of sector specific trade elasticities (either intranational or international) that are individually obtained for each sector. However, for increased efficiency it is also possible to pool the data into a single regression relying on sector specific dummies that, on top of the dummy identifying whether the trade flows are intranational as above, captures the particularities of trade flows in commodities belonging to the same sector. In this pooled regression coefficients other than the intercept and the effect of transport costs are assumed to be homogeneous between commodities. Assuming that parameters such as the origin and destination level effects, the marginal effect of distance, the level effect of borders and the variance or the error term are shared between commodity-groups significantly reduces the number of parameters that need to be estimated, preserves degrees of freedom and therefore allows for more efficient estimation of the remaining parameters of interest.[15]

Thus, in the following specification we interact the transportation costs corresponding to both intranational and international trade flows with a sectoral dummy: $D_{od}^{c}, c = 1, \dots, C$. Apart from the commodity-specific effect of trade costs, we allow for a fixed effect, α^{c} , for each commodity and trade type (international vs intra-national). The extended specification associated with this estimation strategy corresponds to the following equation:

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[14] This requires expressing the trade flows, as the dependent variable, in levels; i.e., without the log transformation.

[15] The sharing of origin and destination level effects between commodities, for example, implies that the number of parameters to be estimated is reduced by 6,968=(268+268)×(14-1) in our main regression, compared to estimating equation (11) separately per commodity.

$$\begin{aligned}\ln V_{id}^{c} = {} & \alpha_0 + \alpha_d + \alpha_o + \alpha^c + \beta_f^c \ln(1+\tau_{od}^c) \times D_{od}^c + \beta_n^c \ln(1+\tau_{od}^c) \times Bord.region_{od} \times D_{od}^c \\ & + \beta_1 \ln Dist._{od} + \beta_2\ Bord.region_{od} + \beta_3\ Bord.country_{od} \\ & + \beta_4 Adj.region_{od} + \beta_5\ Adj.country_{od} + \varepsilon_{od},\ \ o\ \ n, f,\ \ c = 1, \ldots, C.\end{aligned} \tag{12}$$

As before, the foreign and national elasticities of trade are identified from the parameters associated with the bilateral variation in transportation costs: i.e., $\sigma_F^c = 1 - \beta_f^c$ and $\sigma_N^c = 1 - (\beta_f^c + \beta_n^c)$. Besides improving the reliability of results as we show in the empirical section, model (12) also allows to test the differences of parameter estimates obtained for different commodities.

3.3. Measuring trade elasticities at different levels of data aggregation

The theoretical model developed in the second section and the resulting specifications presented above refer to any number of *c*=1,…,*C* sectors, which may correspond to different levels of aggregation (or industry groups) in the existing classifications of trade; e.g., Classification of Products by Activities (CPA), Combined Nomenclature (CN), Standard International Trade Classification (SITC), etc. One of the objectives of our research is to make available not only a set of consistent joint estimates of foreign and national trade elasticities that are new on their own, but also for alternative levels of industrial aggregation. The reason is that potential users of our results may adopt them for their (regional) CGE models at different levels of aggregation. Our lowest level corresponds to that available for the RHOMOLO GCE model (Lecca et al., 2018). In particular, we estimate the elasticities at a 2-digit industrial disaggregation of the Statistical Classification of Products by Activity (CPA, version 2.1) that is an exact mapping of the 2-digit (division) classification of the Standard Goods Classification for Transport Statistics (NST 2007, revision 2)—see Appendix 1.[16] This results in the definition of 14 sectors, which aggregate trade flows in the CPA product space, and whose aggregate value is similar across sectors. The advantage of this aggregation is that each sector has a similar weight on the overall trade flows and therefore we do not need to resort to weighted regressions.

This should provide enough fine-grain parameters for most CGE modelling. However, as we report in the empirical section, elasticity values may vary widely across sectors. Since the results of the models regarding the welfare effects brought about by policy simulations may be sensitive to a disparity of values, modelers usually prefer to use parameters that are common for lower levels of aggregation; which in turn requires estimates obtained for higher classification levels (i.e., one-digit). Consequently, we also provide estimates for the main three CPA categories of tradable goods: A ('Agriculture, forestry and fishing'), B ('Mining and quarrying') and C ('Manufacturing'), as well as one single estimate for the

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[16] The detailed description of the CPA 2.1 and NST 2007, along with their concordance tables can be found at Eurostat's RAMON site: https://ec.europa.eu/eurostat/ramon/index.cfm?TargetUrl=DSP_PUB_WELC.

foreign and national elasticities, which can also be used at all levels of aggregation in both theoretical and empirical work. Our strategy to obtain these estimates does not rely on the aggregation of the trade flow data by sector and averaging independent variables across observations, because it may lead to aggregation and inference bias in log-linear models like the PPML, Lewbel (1992).

Rather than using this approach, we rely on a smaller number of dummies identifying the industrial trade flows, reducing them to just three as previously mentioned: D_{od}^{c}, c =1,…,3, while for the sector specific estimate of foreign and national elasticities using the split sample, no dummy is required. The advantage of this method is that, first, it exploits the existing heterogeneity in all iceberg transport cost to trade flows pairs and, second, it provides econometric consistency across the different levels of aggregation by not changing the sample data of trade flows (as aggregating them would do), since the same information is used in the different industry level regressions. It also ensures that the estimates for higher-level industries can be interpreted as a mean of lower levels, thereby preventing the problems signaled above (i.e., without needing to resort to weighted regression models).

4. Data: Trade flows, generalized transport costs and control variables

The estimation of the trade elasticities through equations (11) and (12), according to the previous sectoral classification and three levels of aggregation, uses the latest available year of the trade flows database corresponding to 2013. The data included in the estimations can be grouped in three categories: 1) Trade flows (quantity and values); 2) generalized transport costs and associated iceberg values, and 3) ancillary control (dummy) variables regarding contiguity (adjacency), which capture border effects when administrative boundaries are considered at the time of segmenting trade flows into national and international trade flows.

4.1.Trade flows

Trade data comes from the latest calculations of the EU REMO team and PBL Netherlands following the methodology proposed by Thissen et al. (2019). These authors estimate a probabilistic trade flows matrix to construct the inter-regional trade flows for all 267 (NUTS-2) EU regions. The methodology relies on 2013 national supply and use tables (SUTs), which are an update of the information of Eurostat SUTs, classified according to NACE Rev. 2, and corresponding to 2010.[17] A general discussion of the methods can be found in Lecca et al. (2018). The Eurostat tables account for the distribution of re-exports over the origin and destination countries, ensure consistency in bilateral trade (i.e., import trade flows are consistent with export trade flows), and, finally, assure that exports and

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[17] The detailed description of the NACE Rev2 classification can be found at Eurostat’s Reference and Management of Nomenclatures (RAMON) site:
https://ec.europa.eu/eurostat/ramon/index.cfm?TargetUrl=DSP_PUB_WELC.

imports of all regions add up to the national aggregates found in the country tables (i.e., top-down compatibility).

In a first step, inter-regional SUTs for 240 NUTS2 regions are estimated using the constrained quadratic minimization procedure by combining the regional Social Accounting Matrices and considering Thissen et al. (2019) data on inter-regional trade flows as priors.[18] In a second step, trade flows for the missing EU regions are estimated. The result is a regional trade matrix that is not only consistent with the regional SUTs, but also as close as possible to the main European transport data.

This matrix is then decomposed into the 14-sectors included in the analysis. However, these trade flows are valued as FOB using mill (factory-gate) prices. Gravity equations (11) and (12) are based on import flows inclusive of all types of iceberg transport costs, corresponding to a CIF denomination of (destination) prices. To convert FOB-denominated flows into CIF values, we need to incorporate non-observable costs related to transport freight insurances. To this aim, we collect data from the International Transport and Insurance Costs of Merchandise Trade (ITIC) database created by the OECD. This database estimates the insurance costs between OECD countries as part of the CIF-to-FOB ratio: (CIF value-FOB value)/(CIF value).[19] We additively sum this ratio to the iceberg transport cost, and interact both with the trade flows in FOB prices to obtain the final import flows in CIF denominated prices. Throughout the analysis, trade flows refer to these import (CIF) values.

4.2. Generalized transport costs

The calculation of the transport costs entering our econometric specification enhances existing approaches based on the minimal cost route between an origin and a destination, taking into account the existing distance and time economic costs from a transport engineering and logistics perspective and the actual road network; see, Combes and Lafourcade (2005), Zofío et al. (2014). Persyn et al. (2020) employ this methodology to calculate a dataset of generalized transport costs (GTCs) for the EU regions. However, their GTCs do not allow for the choice of the optimal type of vehicle used in transportation, depending on shipping distance, degree of urbanization between the origin and destination, and the type of commodity transported.[20]

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[18] For the specific optimizing function and set of restrictions see Thissen et al. (2019: 13-15).

[19] Note that not all EU member states are included in the ITIC-OECD database; these are, Estonia, Malta Romania, Cyprus, Bulgaria, Slovenia and Croatia. We, therefore, assume that a given EU country not included in the database has the same CIF-to-FOB ratio than its closest EU country included in the database with which it shares some communality in terms of geographical or economical features. In particular, we link country-CIF ratios in the following way: Latvia with Estonia; Ireland with Malta; Ireland with Cyprus; Slovakia with Romania; Slovakia with Bulgaria; Slovakia with Slovenia.

[20] As in the previous approaches cited above, they assume that all freight flows are carried by a heavy duty reference articulated truck with 40 tons maximum authorized mass and 5 axles.

This differentiation is crucial in models estimating trade elasticities for several reasons. First, ‘freight curves’ determine the optimal vehicle size depending on the shipping distance between an origin i and destination j, d_{ij} (Jansson and Shneerson, 1982; McCann, 2001). Specifically, ‘freight curves’ identify the vehicle size that minimizes the cost per ton and per unit distance (i.e., €/ton/km). Second, coupled with distance, are the topological characteristics of the transportation network. The most salient feature is the road type, such as expressways, national or local roads, streets, etc., and the most limiting factor restricting the type of vehicle is whether the itinerary passes through urban areas, whose physical characteristics and regulations (based on risk or environmental concerns) only allow for small vehicles (i.e., light vehicles or 2 axle trucks). Hence, short distances corresponding to shipments within urban areas and conurbations (representing the largest proportion of intraregional trade, see Hillberry and Hummels, 2008, and Díaz-Lanchas et al., 2019) are normally performed with this type of vehicles, while for intermediate distances medium size vehicles are preferred (i.e., 3-4 axle trucks), and, finally, longer distances are served with heavy duty vehicles (i.e., articulated trucks with 5-6 axles). Third, the type of vehicle employed for the shipment depends crucially on the commodity transported (e.g., whether the cargo is dangerous, liquid or solid bulk, palletized, containerized, etc.). Both ‘freight curves’ determining the optimal size of the vehicle depending on distance, $s(d_{ij})$, human settlement patterns such as the degree of urbanization between the origin i and destination j, u_{ij}, along with the type of commodity, c, determine the optimal choice of vehicle employed when establishing the distance and time economic costs underlying the GTC. This results in a specific selection of representative vehicles that we employ when calculating the GTCs. Consequently, vehicle specification, v, is a function of the previous variables: $v(s(d_{ij}),u_{ij},c)$.

4.2.1. ‘Freight curves’ and optimal vehicle size

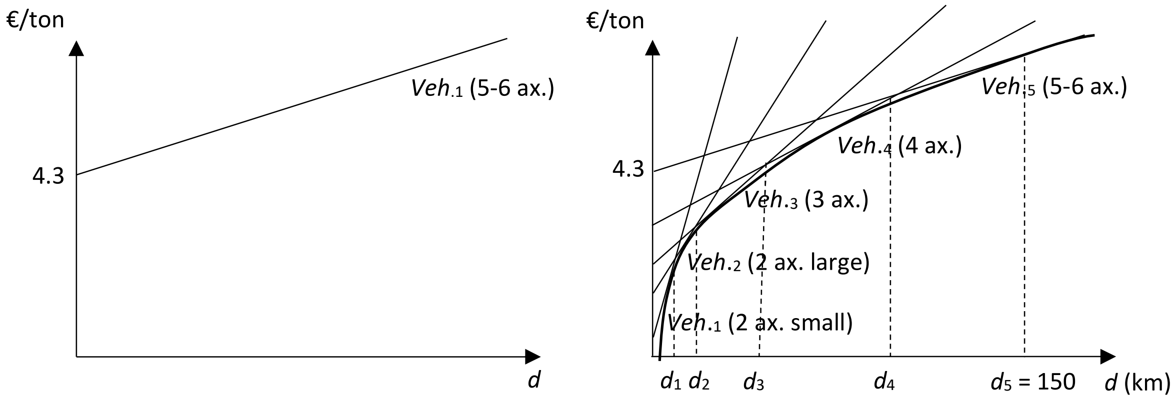
McCann (2001) relies on an inventory optimization approach to prove that under very general conditions the optimal size of a vehicle increases with the haulage distance and weight. In this regard, the choice of optimal vehicle size based on distance hinges upon a balance between economic costs with respect to haulage distance, and transport engineering and handling costs, determined through logistics. Haulage economic costs refer to the annual direct (based on distance and time) and ancillary indirect costs in which transportation firms incur when using a specific vehicle of their fleet. For illustrative purposes and taking the Spanish case as a reference in 2018, the average annual cost of operating a heavy-duty vehicle, HDV, corresponding to a 40 tons articulated truck with 5 axles and a 13.6 meter trailer 4 meters high—the typical ‘workhorse’ of the European road freight industry—is 127,646.89€/year. Handling economic costs refers to time costs associated with loading, unloading and docking operations (the latter including also the time spent in administrative paperwork upon arrival to and departure from the terminal).

While haulage costs are variable by depending on distance,[21] handling costs are fixed and related to single legs (e.g., for the HDV, assuming that it is fully loaded with standard euro pallets, it takes about three hours and a half to complete the whole handling cycle corresponding to docking, loading and unloading logistics, Burdzik et al., 2014).

The relationship between optimal vehicle size and distance is driven by the trade-off between distance related costs expressed in euros per ton per km, that are lower the larger is the vehicle because it can carry a larger payload cargo (e.g., the maximum payload cargo of the HDV is 25 tons), and handling operations whose time costs per ton are higher (as they take longer) the larger is the vehicle (as presented above). This can be clearly seen in Figures 1a and 1b. Figure 1a presents the 'cost line' associated with the HDV, identified as Vehicle 5 (*Veh.* 5), with a 5 or 6 axle configuration. For this vehicle, the line represents the variable cost associated with distance, and whose slope is precisely 0.050€/ton/km, while the handling costs are the intercepts (4.3 €/ton). Fig. 1b presents the 'cost lines' for vehicles increasing in size (as identified by the number of axles) from the smallest vehicle (light vehicle or small truck with 2 axles), *Veh.*1, to the largest one, *Veh.*$_5$ (HDV with 5.-6 vehicles).

When comparing the cost per ton functions for the successive vehicles increasing in size, and the handling costs, the 'freight curve' naturally emerges as the envelopment from below of the successive 'cost lines'. This relationship rests upon a systematically negative relation between the size of a vehicle and its hauling and handling cost per ton.

Figures 1a and 1b. Cost line for the HDV articulated vehicle (1a) and `freight curve' (1b).



Source: Jansson and Shneerson (1982: 226-227)

Based on transport engineering and logistics data, this relationship is observed for the case of road freight transportation. We update the economic costs data for the HDV presented in Zofío et al. (2014: Table 1), and enlarge the database to include four additional

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[21] Annual costs per unit of distance are obtained through dividing by the yearly amount of kilometers covered by the vehicle (e.g., for the HDV it is assumed that it travels 102,000 km per year fully loaded, resulting in 1.251€/km).

vehicles decreasing in size (i.e., from the largest reference vehicle, *Veh.* 5, to the smallest vehicle, *Veh.* 1), as well as handling times from Burdzik et al. (2014). Table 1 presents the set of critical distance thresholds (d_1,..., d_4) that identify the distance at which each vehicle is optimal by minimizing the transportation cost. Each 'cost line' is defined by a fixed cost associated with handling operations that is increasing in vehicle size—column (d), and variable costs corresponding to the hauling distance that are decreasing in vehicle size—column (e). The thresholds reported in the last column (f) are calculated as the intersection points between the successive 'cost lines'. The obtained results show that up to a distance of 10 km, the small vehicle is the optimal choice. The difference between two successive thresholds shows the distance range in which a given size is optimal, i.e., that between the lower and upper thresholds. For example, the rigid vehicle with 3 axles, *Veh.*$_3$, is optimal in the 18 km range between 25 km and 43 km. Finally, aggregating consecutive thresholds yields the distance at which a given vehicle becomes optimal. For the HDV, the cumulated distances show that it is the optimal vehicle choice for shipments longer than 150 km (see also Figure 1b).

Given these results, and the proximity of the distance thresholds, it seems unnecessary to consider all five types of vehicles when calculating the generalized transport costs, thereby reducing the computing time necessary to perform the analysis (particularly when the information regarding optimal vehicle size is coupled with the degree of urbanization and type of commodity as we show next). Consequently, in our analysis, we consider three types of vehicles (shaded in gray in Table 1): the small vehicle that represents the preferred size up to 10 km, the intermediate rigid (3 axles) truck, which is optimal between 35km and 150 km, and the largest HDV, which is the vehicle of choice for shipments longer than 150 km.

To ease the comparison between the economic costs corresponding to each type of vehicle accounting for whether they are variable (depending on distance or time) or fixed, we present in Appendix 2 their corresponding factors of proportionality with respect to the reference HDV considered by Persyn et al. (2020).[22]

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[22] Detailed data on actual monetary values by cost category for these vehicles as in Zofío et al (2014) are available upon request.

Table 1: Distance thresholds for optimal vehicle sizes: handling and hauling costs.[23]

	Maximum Payload (a)	Time costs (b)	Handling		Hauling (e)	Distance (f)
			(c)	(d) = (c)*(b)/(a)		
Vehicle	tons	€/hour	Hours	€/ton	€/km/ton	Km
HDV (5 axl.)	25.0	30.4	3.5	4.3	0.050	72.0
Rigid (4 axl.)	22.3	27.7	3.2	3.9	0.058	43.0
Rigid (3 axl.)	16.0	24.9	2.1	3.3	0.073	25.0
Large (2 axl.)	9.5	22.7	0.9	2.2	0.114	10.0
Small (2 axl.)	6.0	21.0	0.4	1.3	0.206	

Source: Own calculations based on Burdzik et al. (2014), Zofío et al. (2014) and MFOM (2018).

4.2.2. Freight transportation in urban areas

As anticipated, besides the existence of optimal vehicles for alternative distances, $s(d_{ij})$, there are further constraints that limit the use of the above reference vehicles. These constraints refer to road infrastructure (in particular the urban grid or layout) and regulatory legislation (national, regional or city ordinances with respect to traffic congestion, safety, air pollution, etc.). The latter is intended to internalize the negative social and environmental impacts of urban freight transport. For this reason, when calculating the generalized transport costs between an origin and a destination, it is necessary to combine vehicle optimality with respect to distance and the reality of the geographical location in terms of their degree of urbanization. Specifically, city logistics and supply chain management make the small vehicles the only choice for the delivery of goods. There is a complex relationship between the spatial and functional structure of city logistics where the organization and density of land uses (i.e., degree of urbanization) interact with various forms of transport infrastructure, see Giuliano et al. (2019).

Although, cities present a variety of forms and levels of density, each associated with specific urban logistic patterns, the available geographical information from the Global Human Settlement Layer (GHSL) project of the European Commission allows us to differentiate between three urbanization patterns.[24] The GHS model classifies human settlement according to specific rules of population and built-up density and contiguity of

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[23] Maximum payload, time cost and hauling cost are calculated based on information from the Observatory for Road Freight Road Transportation, MFOM (2018). Handling times for the HDV are reported by Burdzik et al. (2014). These include docking, loading and unloading operations. For the rest of vehicles loading and unloading times are calculated using the proportional rule given the capacity of the vehicles. For administrative and docking operations it is assumed that they do not apply to the small vehicle, while they are increasing in time the larger is the vehicle. For convenience in the GTCs calculations distance thresholds have been rounded to nearest whole (natural) number.

[24] See Global Human Settlement (GHS) project: European Commission: https://ghsl.jrc.ec.europa.eu/data.php.

grid cells. Combining satellite information on the density of land use (built-up area) and census data, the GHSL method generates raster data of one square km resolution that differentiates between urban centers, urban clusters, and rural areas. A succession of grid cells presenting a population density larger than 1,500 inhabitants each, or more than 50% of built-up area, with a minimum total population of 50,000 individuals, is classified as an *urban center* (the main requirement is grid contiguity with 4-connectivity and allowing for gap filling). An *urban cluster* is a succession of cells totalizing more than 5,000 individuals, where each cell presents a population density larger than 300 inhabitants. Finally, *rural areas* correspond to a succession of inhabited grid cells without a population threshold, with a total population of less than 5,000 inhabitants.[25]

Combining the information of optimal vehicle size by distance, city logistics and degree of urbanization for distances in the range between 10km and 150km, the choice of the representative vehicle corresponds to the origin-destination matrix presented in Table 2 (for distances shorter than 10 km and longer than 150 km, the preferred vehicles are the small 2 axle truck and the HDV, respectively).

Table 2. Representative vehicles combining optimal size, city logistics and urban patterns.

$10 \text{ km} < d_{ij} \leq 35 \text{ km}$		Destination *j*		
		Urb. Center	Urb. Cluster	Rural
Origin *i*	Urb. Center	Small	Small	Small
	Urb. Cluster	Small	Small	Rigid
	Rural	Small	Rigid	Rigid

$35 \text{ km} < d_{ij} \leq 150 \text{ km}$		Destination *j*		
		Urb. Center	Urb. Cluster	Rural
Origin *i*	Urb. Center	Rigid	Rigid	Rigid
	Urb. Cluster	Rigid	Rigid	HDV
	Rural	Rigid	HDV	HDV

Note: Small vehicle: 2 axles. Rigid vehicle: 3 axles. Heavy duty vehicle (HDV): 5 axles.

4.2.3. Economic costs by commodity

The last dimension in the determination of the optimal vehicle is to account for the type of commodity that is being transported. The reason is that the choice of vehicle depends on

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[25] Here, it is relevant that the GHS project uses grid cells to measure human settlement (built-up area) regardless of administrative boundaries, while census data includes a total count of individuals for administrative units varying widely in in size and shape, as well as population settlement and density within the areas. The GHSL method superimposes these two layers to create the new layer that also disregards administrative boundaries. This layer is segmented in grid cells of 1 km^2, and based on the population and land use thresholds, classifies the territory in the above categories. This constitutes the S-MOD module (settlement model).

the commodity or, more generally, the physical characteristics of the transported cargo in terms of weight and volume. Thus, the standard HDV is the vehicle of choice if the commodity can be transported in standard euro pallets (Burdzik et al., 2014). If perishable goods are transported (e.g., food), then it is necessary a temperature-controlled body made of insulated material and designed to carry temperature-sensitive products (chilled or frozen). Then, if liquids, gases or powders (bulk cargo) are transported, a tank fitted to a chassis is required. Other examples include the transportation of vehicles or containers that require 'skeletal' trailers. Modifications of the above are also necessary in the case of hazardous materials, wide loads, etc.

This variety of commodities results in substantial differences in economic costs across vehicles. Therefore, when calculating the GTCs associated with a given economic sector, where the cargo presents particular characteristics, one needs to control for the costs associated with the choice of vehicle required for transportation. How this is achieved can be easily exemplified for the case of sector 'C19' in the Statistical Classification of Products by Activity in the European Union, Version 2.1, (CPA 2.1), corresponding to "Coke and refined petroleum products". The European Commission provides a matrix relating the CPA 2.1 to the Standard Goods Classification for Transport Statistics, 2007 (NST 2007), according to which shipments are classified in the European Freight Road Transportation survey (ERFT). This survey allows us to ultimately identify the type of cargo and associated vehicle. Reading the matrix of correspondences, sector 'C19' in the CPA 2.1 presents a one-to-one match with division 07 in the NST 2007: "Coke and refined petroleum products". Hence tabulating the data on commodities transported in the ERFT classified according to the NST 2007 and their associated type of cargo, one finds that for this particular sector the cargo corresponds mainly to liquid goods in bulk, 90.2% (of which 82.4% are dangerous—gasoline, gas, etc.—and the remaining 7.8% are non-dangerous), and solid goods in bulk, 9.8% (of which 5.9% are dangerous—solid or waxy refined petroleum products—and the rest, 3.9%, are not).[26] Using the ERFT surveys for 2011-2014 we are able to match the commodity transported and corresponding vehicle.

Appendix 3 presents the commodity factors that either increase or decrease the economic costs for each type of commodity, taking as reference the standard HDV. For example, while the cost of the HDV is 1.251€/km, that of a tanker increases to 1.590€/km (the annual costs in 2018 are 143,062.89€/year, and assuming that it covers 90.000km/year then the cost is 1.590€/km). Hence, the commodity factor between these two vehicles is f^c = 1.280. Since the commodities belonging to a given NST 2007 classification are transported with a combination of vehicles (e.g., dangerous and non-dangerous), the economic factors

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[26] In the European Freight Road Transportation survey, the specific goods-related variables (A3) are the type of good and vehicle, A3_1 (Type of goods, NST 2007), A3_3 (Classification of dangerous goods) and A3_4 (Type of cargo). The matching between the type of cargo and the most suitable vehicle comes from the information provided by the Spanish Observatory of Freight Road Transportation, MFOM (2018).

are the average of the cost of the different vehicles weighted by the share of shipments transported by each type of vehicle.

4.2.4. Calculating the generalized transport costs

Following Persyn et al. (2020), but allowing for the optimal type of vehicle depending on distance, urban characteristics, and commodity transported, $v(s(d_{ij}), u_{ij}, c)$, we denote by GTC_{ij}^{v} the generalized transport cost corresponding to the cheapest itinerary, I_{ij}^{v*}, among the set of possible routes, I_{ij}^{v} of moving vehicle *v* between origin *i* and a destination *j*. The itineraries are comprised of different arcs a_c, with an associated set of physical and legal attributes (i.e., maximum legal speed), $\mathbf{x}_{a_c}$. The primary physical attributes of an arc are its distance, d_a, road type, r_a, and gradient (steepness), g_a. The arc speed, s_{a_c}, is derived from these properties, and thereby it is possible to determine the time it takes to cover it, $t_{a_c}^{t}$ = $d_a^t / s_{a_c}^t$.

The generalized transport cost for a given commodity *c*, GTC_{ij}^{c}, corresponds to the solution to the following problem:

$$GTC_{ij}^{c} = f^{c} GTC_{ij}^{v} = f^{c} \min_{I_{ij} \in \mathbf{I}_{ij}} \left(DistC_{ij}^{v*} + TimeC_{ij}^{v*} \right) + Taxes_{ij}^{v} + Vignette_{ij}^{v} + Handling_{ij}^{v}, \tag{13}$$

where

$$\begin{aligned} DistC_{ij}^{v} &= \sum\nolimits_{a \in I_{ij}} \left(\sum\nolimits_{k} e_{ak}^{d} f_{ak}^{vd} \right) d_a = \\ &= \sum\nolimits_{a \in I_{ij}} \left(fuel_a^{v} + toll_a^{cv} \right) d_a + \left(tireCS^{v} + maintCS^{v} \right) \left(fuel_a^{v} d_a \right), \end{aligned} \tag{14}$$

$$TimeC_{ij}^{v} = \sum\nolimits_{a \in I_{ij}} \left(\sum\nolimits_{k} e_{ak}^{v} f_{ak}^{vt} \right) t_a = \sum\nolimits_{a \in I_{ij}} \left(1 + amortFinCS_a^{v} + insurCS_a^{v} + indCS \right) \left(t_a lab_{ij}^{v} \right). \tag{15}$$

Compared to Persyn et al. (2020), the GTC in (13) has been enhanced by allowing for the choice of the optimal type of vehicle, $v(s(d_{ij}), u_{ij}, c)$.[27] Thus, the original distance and time costs of the HDV considered by these authors, e_{ak}^{d} and e_{ak}^{t} (where *k* denotes cost per

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[27] For a detailed discussion of each of the distance and time economic costs e_{ak}^{d} and e_{ak}^{t} (in € per km), see Persyn et al. (2020). The main components of distance cost are fuel costs ($fuel_a$), which is computed as the fuel price (in € per liter) multiplied by the fuel consumption of the reference vehicle, and toll costs ($toll_a$), which are specific to each member state because of differences in nation-wide tolling policies (e.g., either through vignettes, or a country-wide electronic toll), or also per road-segment. The main time cost is the labor cost of the driver ($t_a lab_{ij}$). The hourly wage cost lab_{ij} from Eurostat is multiplied by the time (in hours) it takes to cross the arc. Labor costs correspond to the average wages at origin and destination. The remaining costs are proportional to the cost shares (*CS*) of these main components, based on the cost structures provided by the Spanish Observatory of Freight Road Transportations in 2018 (MFOM, 2018).

km), are modified by applying the individual vehicle factors corresponding to distance and time costs: f_{ak}^{vd} and f_{ak}^{vd} (Appendix 2), thereby obtaining the new costs at the arc level $e_{ak}^{vd} = e_{ak}^{d} f_{ak}^{vd}$ and $e_{ak}^{vd} = e_{ak}^{d} f_{ak}^{vd}$. Unfortunately, from a practical perspective, and due to lack of data, it is impossible to control for commodity attributes at the arc level (e.g., such as legal traffic restrictions depending on hazardousness). Therefore, when calculating the minimum cost along the optimal itinerary, only the information on distance and urban degree is considered, resulting in GTC_{ij}^{v} (the latter proxing the existence of legal restrictions). For this reason, the origin-destination GTC associated with each commodity *c* as presented in (13), GTC_{ij}^{c}, is the result of multiplying this baseline GTC_{ij}^{v}, corresponding to the vehicle of choice, by the commodity factor f^c.

The final generalized transport cost between any two regions is the average of numerous GTC_{ij}^{c} calculated between a random sample of origin and destination centroids, each drawn from a one square km population density grid. Thus, we calculate the GTC between two regions *o* and *d* as the arithmetic mean of the GTC between the I centroids belonging to region *o*, indexed by $i=1,\dots,I$, and the J centroids belonging to region *d*, indexed by $j=1,\dots,J$. The final inter-regional GTC for a given commodity *c* corresponds to: $GTC_{od}^{c} = \frac{1}{IJ}\left(\sum_{i} \sum_{j} GTC_{ij}^{c}\right)$. In the above calculations, it is possible to identify the GTC associated with each type of vehicle that is used between each centroid pair, $GTC_{od}^{c,v}$. Once the average is taken, we can recover the percentage shares associated with each one of the three vehicles, $s_{od}^{v} \geq 0, \sum_{v=1}^{3} s_{od}^{v} = 1$. Also, we note that, as a result of the region-specific distance and time costs, the bilateral generalized transport costs are asymmetric; i.e., $GTC_{od}^{c} \neq GTC_{do}^{c}$.[28]

4.3. *Iceberg* (*ad valorem*) *transport costs*

We are now ready to present the calculations of the iceberg transportations costs that are included in the econometric specification obtained from our trade model (11). In practice, we have seen that actual (generalized) transportation costs depend on a number of characteristics related to the choice of vehicle. Following Persyn et al. (2020), we can take advantage of the GTC calculations when defining the ad valorem transportation cost between any two regions for each trade sector. Considering that we can match trade flows classified according to the CPA 2.1 with their corresponding generalized transport costs $GTC_{od}^{c,v}$ following the NST 2007 classification (Appendix 1), we define the iceberg transport cost τ_{od}^{c} as follows:

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[28] Waugh (2007) highlights the importance of asymmetric bilateral trade costs for explaining observed bilateral trade flow patterns and relative price and real per capita income differences between countries.

$$\tau_{od}^{c}=\frac{F_{od}^{c}\sum_{v=1}^{3}\left(\frac{s_{od}^{v}}{L_{od}^{v}}\right)GTC_{od}^{c,v}}{V_{od}^{c}}=\frac{\sum_{v=1}^{3}\left(\frac{s_{od}^{v}}{L_{od}^{v}}\right)GTC_{od}^{c,v}}{P_{o}^{c}},\ s_{od}^{v}\geq 0,\ \sum\nolimits_{v=1}^{3}s_{od}^{v}=1,\quad o=n,f, \tag{16}$$

where F_{od}^{c} (tons) and V_{od}^{c} (€) are the quantity and value of the trade flows in origin; $GTC_{od}^{c,v}$ (€/veh.) is the generalized transport cost for each vehicle size, calculated as in (13); s_{od}^{v} are the shares of each vehicle in the bilateral shipments between regions; and, finally, L_{od}^{v} (tons/veh.) is the average load of the shipments. The information on vehicles shares s_{od}^{v} and average loads L_{od}^{v} is obtained from the European Freight Road Transportation (ERFT) survey by segmenting the sectoral shipments according to the maximum permissible laden weigh, and calculating the ratio of actual payload to maximum payload.[29] The numerator in expression (16) calculates the number of vehicles necessary to ship the quantity F_{od}^{c} according to the current distribution of vehicles, by multiplying the number of required vehicles by their generalized transport cost. Subsequently, the transport cost is related to the value of the shipments, yielding the ad valorem value.

Also, as the second equality shows, the ad valorem aggregated transport cost can be related to the unit price in origin corresponding to each sector P_{o}^{c}. Although in principle it would be possible to recover information on unit prices at the regional level from the ERFT, there are multiple sector-origin-destination triplets that have either missing or too few values, preventing the calculation of reliable figures. For this reason, we rather rely on EUROSTAT's Community External Trade Statistics (COMEXT) database that allows the calculation of unit prices at the national level. COMEXT gives detailed statistics on external trade for each EU member state by type of product and export and import source. For each

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[29] As already mentioned, and in contrast to Persyn et al. (2020), our iceberg transport cost specification accounts for the variability of the type of vehicle used in the shipments, which should capture the reality of transport costs in short distances. We also consider the different average loads across origin-destination pairs by type of vehicle. This is because it is well known that the load factor (asymmetrically) depends on *od* and the type of good transported (e.g., automobile-carrying vehicles, just like tanker trucks will by their very nature complete at least half of their trips empty– between 45% and 50%. In the case of the standard HDV, with vehicles carrying all types of cargo, hauling them to many locations, productivity in terms of the average load will depend on several factors. For example, in countries with predominantly national transport (like Germany or France) with shorter journeys and a strong commercial presence on the territory, the empty run rate will be low (e.g., less than 20% in Germany, and 13% in France). To be noted that in Spain, where transport increasingly tends to focus on the national territory, the empty run rate is also low, approximately 15%. In addition, in these countries, consolidations are widely applied, which allow to increase the vehicles' load factor. More than half of loads are made up of consolidations (https://teleroute.com/en-en/).

CPA 2.1 sector and country of origin unit prices are calculated as $P_{od}^{c} = \sum_{D} F_{od}^{c} / \sum_{D} V_{od}^{c}$; i.e., tons and value are aggregated for all combined EU states.[30,31]

Table 3 summarizes the information on the iceberg transport costs τ_{od}^{c} by CPA sector, as well as the variables GTC_{od}^{c} and P_{od}^{c} entering its calculation. The information is also differentiated depending on the nature of the trade flow in terms of the elasticities of interest: foreign (international flows between countries) and national (interregional trade flows within countries). As expected, both generalized transport costs and unit prices are in general larger for international trade flows than national ones, resulting in lower iceberg transport costs. To illustrate the relationship between the iceberg transport costs and its components, we have calculated the average values of these three variables by quintiles of GTC_{od}^{c}. Results are reported in Appendix 4, along with the boxplots chart of the distribution of the iceberg transport costs by the same quintiles. It can be seen that both the iceberg and generalized transport costs are increasing in distance, but unit prices tend to be stable in accordance with Table 3. Given the spatial distribution of economic activity within the EU, region-pairs in higher distance-quintiles tend to be more peripheral and less developed. This may explain why unit prices do not monotonically increase when considering trade within higher GTC quintiles as was found by Behrens and Brown (2018) for Canada (where in contrast to the EU, the geographic center is less developed, and regions/state at larger distances on average are more developed). We complete the presentation of the iceberg transport costs in Appendix 5 by depicting the same graphs for each CPA sector. The wide range of τ_{od}^{c} is clearly observed. The lowest values are observed for the trade flows of heavy industries because of its relatively high unit prices; i.e., sector C25, 'Fabricated metal products'. On the contrary, the greater taus are observed in sectors whose unit value is low, combined with relatively low generalized transport costs; e.g., sector B. 'Mining and quarrying'.

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[30] We match the combined nomenclature (CN) and CPA classification using the concordance matrix tables available at Eurostat's RAMON site: https://ec.europa.eu/eurostat/ramon/index.cfm?TargetUrl=DSP_PUB_WELC.

[31] Even following this approach, we encounter outliers associated to measurements errors. Therefore, we follow similar strategies to those applied in the literature by filtering the data; e.g., Hertel et al. (2007) and Behrens and Brown (2018). Specifically, we rely on the interquartile range rule. For each CPA sector and by GTC_{od}^{s} quintiles (as presented in Appendix 4), we exclude unit values and iceberg transport costs that are smaller and greater than one and a half times the interquartile range of their distributions, 1.5×IQR = 1.5× (75th percentile – 25th percentile).

Table 3. Iceberg, generalized transport costs and unit prices.

Var. CPA	$\overline{\tau}^c_{od}$	$\overline{\tau}^c_{od}$ Foreign	$\overline{\tau}^c_{od}$ National	$\overline{GTC}^c_{od}$	$\overline{GTC}^c_{od}$ Foreign	$\overline{GTC}^c_{od}$ National	$\overline{P}^c_{od}$	$\overline{P}^c_{od}$ Foreign	$\overline{P}^c_{od}$ National
CPA_A01	0.343	0.359	0.145	2,259	2,388	670	427	431	375
CPA_A02-A03	0.832	0.874	0.315	2,259	2,388	670	137	139	121
CPA_B	1.236	1.302	0.423	2,690	2,844	791	26	25	30
CPA_C10-C12	0.180	0.189	0.068	2,140	2,262	636	723	729	652
CPA_C13-C15	0.081	0.085	0.029	2,015	2,130	600	2,606	2,609	2,567
CPA_C16-C18	0.131	0.136	0.058	2,018	2,133	602	1,167	1,183	959
CPA_C19	0.219	0.231	0.071	2,489	2,632	740	681	683	653
CPA_C20-C22	0.477	0.503	0.153	2,171	2,295	646	343	341	375
CPA_C23	0.318	0.335	0.113	2,410	2,548	712	572	577	512
CPA_C24	0.307	0.322	0.126	2,113	2,234	629	421	421	414
CPA_C25	0.016	0.017	0.006	2,113	2,234	629	8,159	8,142	8,361
CPA_C26-C28	0.093	0.097	0.036	2,112	2,233	630	2,245	2,246	2,235
CPA_C29-C30	0.139	0.147	0.046	2,063	2,180	616	1,678	1,680	1,653
CPA_C31-C32	0.730	0.768	0.261	2,017	2,133	601	249	249	253

Notes: Average values. Own elaboration.

4.4. Control variables

Finally, ancillary variables such as simple geographical distances and adjacency are included in the analysis to capture idiosyncratic characteristics that are customarily taken into account in trade, while ensuring that the variability of the iceberg transport costs corresponds to all the variables included their calculation as presented in the previous section. Distances between regions (between the physical centroids of the regions), as well as information about contiguity of regions and countries, are computing using the Geodata on Administrative Units provided by Eurostat GISCO.

5. Results

5.1. Individual estimation of (intra)national and foreign (international) elasticities by sector

We report first the results obtained from estimating the foreign and (intra)national trade elasticities for each of the 14 sectors individually—eq. (11)—in Table 4. Based on the statistical significance of the baseline parameters β^c_f, driving foreign elasticities σ_F, and β^c_n, capturing the additional marginal effect corresponding to (intra)national trade flows, σ_N, we observe that these coefficients are significant in 8 and 5 sectors, respectively. But only in 2 of these sectors (out of 14) they are simultaneously significant: sector C24, 'Basic metals', and sector C29-30 (including 'Motor vehicles trailers and semi-trailers', C29, and 'Other transport equipment', C30).[32]

Based on the values of the underlying parameters we calculate the magnitude of the corresponding elasticities, reported in the first two rows of Table 4, and test their statistical significance. There are 10 sectors for which the foreign elasticity of substitution, $\sigma_F^c = 1 - \beta_f^c$, is significantly different from one, with values that range between $\sigma_F^{A02-A} = 0.980$ ('Products of forestry', A02, and 'Fishing', A03) and $\sigma_F^{C25} = 50.391$ ('Fabricated metal products').[33] Nevertheless, in 8 out of the 10 sectors, foreign elasticities present values in line with those reported in the previous literature for international trade flows using the same sector by sector estimation strategy; i.e., $\sigma_F^c < 4$. Combining the results obtained for the β_f and β_n parameters we can recover the elasticity corresponding to (intra) national trade (or interregional trade within the same country), $\sigma_N^c = 1 - (\beta_f^c + \beta_n^c)$. Note that regardless the statistical significance of its underlying parameters, σ_N^c can be statistically different from one. A good example is sector C16-18 ('Wood', C16; 'Paper' C17; and 'Printing products', C18), whose individual parameters are not statistically significant from zero, yet they are jointly at the 10% confidence level, resulting in $\sigma_N^{C16-C} = 9.652$. Altogether, there are 11 sectors for which the national elasticities of substitution are statistically significant, exhibiting a positive sign.[34] Intranational elasticities σ_N^c range between the smallest value observed in sector $\sigma_N^{C31-C} = 2.559$ ('Furniture', C31, and 'Other manufactured goods', C32) and the largest value, $\sigma_N^{C25} = 49.431$ ('Fabricated metal products').

The third rows in both panels of Table 4 summarize if foreign and national elasticities differ from each other statistically and, if they do, what is the direction of the inequality; i.e., whether σ_F^c >=< σ_N^c. Despite their statistical significance, in 6 sectors national trade elasticities are greater than their foreign counterparts, $\sigma_F^c < \sigma_N^c$, while in another 6 the hypothesis that they are equal, $\sigma_F^c = \sigma_N^c$, cannot be rejected. This latter figure includes the relevant outcome when both elasticities are equal to each other but clearly different from 1 (5 cases), and the border case in which the foreign is barely different from one at the 10% significance level (in sector are A02-03 ('Products of forestry', A02, and 'Fishing', A03)). Finally, in only two cases, foreign elasticities are greater than national elasticities, $\sigma_F^c > \sigma_N^c$, but this includes sector C29-30 which exhibits the wrong sign.

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[32] However, in the latter sector, the sign corresponding to the national effects is positive, $\beta_N^{C29-C} = 8.190$, which ultimately results in a *negative* trade elasticity: $\sigma_N^{C29-C30} = -5.104$. Note that obtaining a negative elasticity is an exception, since all other positive coefficients (with rather small values) are not statistically different from zero.

[33] Although the standard errors of the foreign elasticities σ_F coincide with those of their associated parameter β_f, we have tested whether the values differ from 1.

[34] Unavailable sectors are A02-A03 ('Products of forestry', A02, and 'Fishing', A03) and C13-C15 ('Textiles', C15, 'Wearing apparel', C16, and 'Leather Products', C17), and the previously mentioned sector C29-C30, whose elasticity presents the wrong sign.

Therefore, we conclude that the individual sector by sector estimations reported in Table 4 broadly suggest that the national elasticities are larger than the foreign ones. This is confirmed by the median value of the national elasticities across all sectors standing at 6.624, much higher than the median of the elasticities for international trade at 2.555. A result that is later confirmed in the following section reporting the results from the pooled estimation.

As for the rest of the control variables, they present the expected sign and significance. The estimated parameter for the log of distance ($\ln Dist_{id}$) is always negative and generally significant, while those associated to the regional and national border dummies capturing trade within the same region and/or country ($Bord.region_{od}$ and $Bord.country_{od}$), as well as geographical adjacency ($Adj.region_{od}$ and $Adj.country_{od}$), are also in general positive and significant. Correlation coefficients are also high in the range 0.730 and 0.932.

Finally, given our preference for the pooled approach to estimate the trade elasticities, as justified in the econometric section 3.2, we do not pursue here the sector by sector strategy to estimate macro-elasticities for each of the three higher levels of the CPA classification: A (Agriculture, forestry and fishing), B (Mining and quarrying) and C (Manufacturing).

Table 4. Micro foreign (international) and national elasticities of trade, individual sectors.

Sector Variable	A01	A02-A03	B	C10-12	C13-14-15	C16-17-18	C19
$\sigma_F^c = 1 - \beta_f^c$	0.942	0.980*	2.762***	1.803	16.166**	5.204	0.693
$\sigma_N^c = 1 - (\beta_f^c + \beta_n^c)$	8.081***	0.700	3.186**	24.246***	6.802	9.652*	7.075***
σ_F^c >=< σ_N^c	<	=	=	<	>	<	<
β_f^c	0.058	0.020	-1.762**	-0.803	-15.166**	-4.204	0.307
	(0.954)	(0.515)	(0.761)	(1.837)	(7.335)	(3.257)	(1.083)
β_n^c	-7.140***	0.280	-0.424	-22.44***	9.364	-4.448	-6.383***
	(1.333)	(0.707)	(1.279)	(6.709)	(8.833)	(5.097)	(2.183)
ln*Dist.*	-0.231	-0.456***	-0.282**	-0.307**	-0.391***	-0.560***	-0.349***
	(0.154)	(0.155)	(0.116)	(0.150)	(0.092)	(0.090)	(0.064)
Border.Reg	2.590***	1.899***	2.084***	2.047***	0.469	1.981***	1.218***
	(0.551)	(0.396)	(0.263)	(0.385)	(0.323)	(0.270)	(0.236)
Border.Country	3.837***	4.064***	3.205***	4.412***	3.321***	2.272***	4.254***
	(0.313)	(0.464)	(0.873)	(0.540)	(0.999)	(0.550)	(0.318)
Adj.Region	0.992***	0.664***	1.002***	0.839***	0.278***	0.434**	0.573***
	(0.157)	(0.164)	(0.235)	(0.136)	(0.105)	(0.183)	(0.125)
Adj.Country	-1.167***	0.177	-0.866	-0.559	0.074	-0.332	-0.404
	(0.329)	(0.512)	(0.739)	(0.580)	(0.721)	(0.354)	(0.336)
R^2	0.897	0.899	0.870	0.932	0.863	0.889	0.917
Nº Observations	69,696	68,644	69,696	69,696	69,696	69,696	69,169

Notes: Importer and exporter fixed effects; Region-pair clustered standard errors in parenthesis.
Significance Levels: * p<0.10, ** p<0.05, *** p<0.01

Sector Variable	C20-21-22	C23	C24	C25	C26-27-28	C29-30	C31-32
$\sigma_F^c = 1 - \beta_f^c$	2.592***	2.518***	3.814***	50.391***	3.924***	3.086***	1.959***
$\sigma_N^c = 1 - (\beta_f^c + \beta_n^c)$	2.942***	11.061***	6.172*	49.431**	8.877*	-5.104**	2.559***
σ_F^c >=< σ_N^c	=	<	<	=	=	> (Wrong)	=
β_f^c	-1.592***	-1.518	-2.814***	-49.391***	-2.924***	-2.086**	-0.959***
	(0.551)	(0.949)	(0.859)	(11.409)	(1.113)	(0.096)	(0.286)
β_n^c	-0.350	-8.542***	-2.358*	0.963	-4.953	8.190***	-0.640
	(0.660)	(2.557)	(1.277)	(18.786)	(4.883)	(2.390)	(0.667)
ln*Dist.*	-0.181*	-0.202	-0.087	-0.385***	-0.282***	-0.482***	-0.335***
	(0.094)	(0.161)	(0.099)	(0.105)	(0.074)	(0.067)	(0.058)
Border.Reg	0.597**	2.555***	0.835**	1.490***	1.308***	1.135***	1.149***
	(0.259)	(0.416)	(0.356)	(0.329)	(0.259)	(0.256)	(0.230)
Border.Country	2.965***	3.659***	3.228***	3.644***	2.172***	0.939***	2.601***
	(0.240)	(0.456)	(0.351)	(0.280)	(0.270)	(0.278)	(0.241)
Adj.Region	0.226*	1.121***	0.299**	0.746***	0.640***	0.541***	0.575***
	(0.120)	(0.198)	(0.122)	(0.118)	(0.141)	(0.126)	(0.102)
Adj.Country	0.331	0.834***	0.945***	0.279*	0.419***	0.348**	0.811***
	(0.207)	(0.222)	(0.252)	(0.149)	(0.121)	(0.157)	(0.143)
R^2	0.769	0.908	0.887	0.919	0.808	0.730	0.867
Nº Observations	69,696	69,696	69,696	69,696	69,696	69,696	68,644

Notes: Importer and exporter fixed effects; Errors clustered by region-pair;
Significance Levels: * p<0.10, ** p<0.05,*** p<0.01

5.2. Pooled estimation of (intra)national and foreign (international) elasticities

The standard method of estimating trade elasticities sector by sector can be compared to that of pooling the trade data as presented in eq. (12). This specification introduces the interaction between the transportation costs and their corresponding sectors to identify foreign elasticities of trade, and again with a dummy variable capturing whether the trade flow takes place between regions within a country to identify national elasticities of trade. Contrary to eq. (11) the advantage of this specification in that it yields a single value for the common variables that control for distance, border and adjacency effects, while allowing for a larger number of observations and thus more efficient parameter estimation.

Table 5 reports the results for sectoral micro-elasticities. Now all foreign and national elasticities are significantly different from 1, except for the foreign elasticity in sector C20-22 (including 'Chemicals', C21; 'Pharmaceutical', C22, and 'Rubber products', C22). As in Table 4 the third row summarizes whether foreign elasticities of trade σ_F^c = $(1-\beta_f^c)$ differ from their national counterparts σ_N^c = $1-(\beta_f^c + \beta_n^c)$. Under this specification, we now find that foreign and national trade elasticities are in most cases statistically different from each other. This is the case in 9 of the 14 sectors, with national elasticities being consistently greater than foreign elasticities in these sectors ($\sigma_F^c < \sigma_N^c$). Regarding the common variables, they present the expected sign and significance. In addition, the R^2 is satisfactory at 0.823. As opposed to the split sample approach of Hummels (2001) and Hertel et al. (2007) previously used, we remark that this estimation strategy, providing better efficiency, seems to be the appropriate one when recovering the two levels of trade elasticities corresponding to foreign and national goods. The former approach producing less precisely estimated parameters. It is perhaps not surprising that the less efficient split-sample (sector by sector) approach struggles to produce precise parameter estimates in a context where there are no tariffs, and identification rather hinges on relatively small differences in interregional differences in transport cost caused by geography, infrastructure and other factors affecting trade flows, after controlling for physical distance.

Table 5. Micro foreign (international) and national elasticities of trade, pooled sectors.

Sector / Variable	A01	A02-03	B	C10-12	C13-14-15	C16-17-18	C19
$\sigma_F^c = 1 - \beta_f^c$	4.999***	3.598***	3.838***	13.200***	12.970***	13.780***	6.773***
$\sigma_N^c = 1 - (\beta_f^c + \beta_n^c)$	7.259***	3.138**	6.264***	22.634***	13.726*	27.735***	5.496***
σ_F^c >=< σ_N^c	=	=	<	<	=	<	=
β_f^c	-3.999***	-2.598***	-2.838***	-12.200***	-11.970***	-12.780***	-5.773***
	(0.984)	(0.679)	(0.968)	(2.724)	(3.668)	(2.258)	(1.436)
β_n^c	-2.260	0.460	-2.426***	-9.437**	-0.757	-13.950***	1.277
	(2.615)	(1.322)	(0.854)	(3.895)	(7.290)	(4.216)	(1.905)
	C20-21-22	C23	C24	C25	C26-27-28	C29-30	C31-32
$\sigma_F^c = 1 - \beta_f^c$	1.490***	6.204***	3.597***	156.400***	4.202***	2.997***	1.609***
$\sigma_N^c = 1 - (\beta_f^c + \beta_n^c)$	1.843*	10.906***	9.306***	124.213***	29.361***	24.332***	2.874***
σ_F^c >=< σ_N^c	<	<	<	=	<	<	<
β_f^c	-0.490	-5.204***	-2.597***	-155.400***	-3.202**	-1.997*	-0.609**
	(0.355)	(0.790)	(0.635)	(17.121)	(1.445)	(1.045)	(0.270)
β_n^c	-0.353	-4.702*	-5.709***	32.140	-25.16***	-21.33***	-1.265*
	(0.997)	(2.507)	(2.100)	(31.899)	(8.578)	(5.525)	(0.760)
Common Variables	*LnDist*	*Border. Region*	*Border. Country*	*Adjacent Region*	*Adjacent Country*	R^2	Nº Observations
	-0.135***	1.969***	2.893***	0.711***	0.125	0.823	975,744
	(0.044)	(0.245)	(0.241)	(0.104)	(0.170)		

Notes: Importer and exporter fixed effects; Errors clustered by region-pair.
Significance Levels: * p<0.10, ** p<0.05,*** p<0.01

The results obtained for the macro-level elasticities resulting from grouping all trade flows into the three main NACE categories are reported in Table 6. As discussed in section 3.3, we recall that we do not aggregate the data but rely on sectoral dummies that identify the sector of each trade flow. For each of the three sectors: A ('Agriculture, forestry and fishing'), B ('Mining and quarrying') and C ('Manufacturing'), we observe that the estimated foreign elasticity is always significantly larger, although the difference is not significant in a statistical sense for sector A. Finally, we estimate the single macro-elasticity for both foreign and national trade flows, without differentiating among sectors. These global results are shown in the last column of Table 5. Once again, the estimated values are reasonable from an economic point of view and statistically different from one, with the national elasticity being significantly larger than the foreign one. We now proceed to discuss the numerical values of the micro- and macro-elasticities in light of previous results obtained in the literature.

Table 6. Macro foreign (international) and national elasticities of trade, pooled sectors.

Sector Variable	A Agriculture, forestry, and fishing	B Mining and quarrying	C Manufacturing	All sectors
$\sigma_F^c = 1 - \beta_f^c$	2.661**	2.906***	1.670***	2.156***
$\sigma_N^c = 1 - (\beta_f^c + \beta_n^c)$	4.573***	5.510***	4.846***	4.652***
σ_F^c >=< σ_N^c	=	<	<	<
β_f^c	-1.661**	-1.906**	-0.670*	-1.156***
	(0.691)	(0.933)	(0.368)	(0.415)
β_n^c	-1.913	-2.604***	-3.175***	-2.449***
	(1.626)	(0.883)	(0.969)	(0.614)
ln*Dist.*	-0.366***			-0.360***
	(0.046)			(0.046)
Border.Reg	1.544***			1.568***
	(0.256)			(0.254)
Border.Country	2.984***			2.923***
	(0.218)			(0.206)
Adj.Region	0.672***			0.683***
	(0.125)			(0.126)
Adj.Country	0.299*			0.275*
	(0.166)			(0.161)
R^2	0.812			0.811
Nº Observations	975,744			975,744

Notes: Importer, exporter and sector fixed effects; Errors clustered by region-pair.
Significance levels: * p<0.10, ** p<0.05,*** p<0.01

5.2.1. Foreign (international) elasticities of trade

Foreign elasticities of trade at the 2-digit CPA (micro) level, presented in Table 5, range from the minimum observed in sectors C31-32 (including 'Furniture', C31, and 'Other manufactured goods', C32), $\sigma_F^{C3\ -32}$ = 1.609, and the maximum observed in sector C25, 'Fabricated metal products except for machinery and equipment', σ_F^{C25} = 156.400. This latter value represents an extreme case resulting from the large concentration of trade at short distances, and is one order magnitude larger than the next value corresponding to sector C16-18 (including 'Wood', C17, 'Paper', C16, and 'Printing products', C17), σ_F^{C16-1} = 13.780. For comparison purposes with the traditional (split) estimation approach reported in the previous section, the median value of foreign elasticities is now 4.601. Foreign trade elasticities are smaller than 7 in 9 sectors (out of 14), with their corresponding national counterparts doubling their value when they are statistically different. These values of foreign elasticities for trade between EU countries are in line with those reported in the international trade literature relying on trade flows from projects such as GTAP (World data), the Michigan model (US), USAGE (US) and MONASH (Australia), using tariffs as identification variable, and time series or cross-sectional analyses as econometric approaches. Comparing our results to those surveyed in Table 1 by Hillberry and Hummels (2013; 1,221) for multicountry (including some EU countries or the block as a whole) and single-country models, their range of elasticities is [0.9, 34.4]. As the level of sectoral aggregation is similar to ours, we confirm that our estimates of comparable (i.e., foreign) trade elasticities are in accordance with those reported in previous studies (see also Table 1 in Hertel et al., 2007).

There are also a few studies reporting Armington elasticities between EU countries using different econometric approaches and for specific sectors; i.e., Németh et al. (2011), Welsch (2008) and Olekseyuk and Schürenberg-Frosch (2016). The first two references focus on energy intensive sectors. Németh et al. (2011) use the so-called GEM-E3 model aimed at capturing the interactions between economy, energy and the environment in a general equilibrium modelling framework.[35] Using the European version of the model, they report short and long-term Armington elasticities, which are estimated relying on a panel data analysis econometric framework that uses dynamic adjustments. The dataset covers yearly data for the 1995–2005 period and the range of elasticities between domestically produced and imported goods (home-foreign goods) for seven energy-intensive sectors is [0.6; 1.7].[36] These values are particularly low in light of the elasticities reported by Hillberry and Hummels (2013) and our own estimates, whose minimum value, $\sigma_{F}^{C31\_32}$ = 1.609, is even above their upper bound.[37] On their part, Olekseyuk and Schürenberg-Frosch (2016) estimate country-specific Armington trade elasticities from trade data between eight EU countries for selected manufacturing sectors. They use a panel data set constructed from the STAN-OECD and EUROSTAT's PRODCOM databases (for different ISIC classifications) covering the period 1995-2011. As for the estimation methods, they consider single-sector co-integration time series analysis and, when the sample size is insufficient to recover the elasticities, turn to a fixed effects panel data model that coincides with our cross-section approach. By pooling the data for neighboring sectors in the product space, they are capable of increasing the number of observations (i.e., the number of degrees of freedom) and, thus, the accuracy of the results and the test statistics. Regarding the use of time series, they adopt co-integration methods because their estimates show that for most countries both the price and quantity ratio series are non-stationary, but integrated of order one or two. The range of elasticities for the manufacturing sectors considered in their study is [0.300; 3.670]. As for the panel data results, their pooled fixed effects estimations yield trade elasticities in the range [0.320; 2.430]. Focusing on the goodness of fit, we highlight

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[35] For details on the model see https://ec.europa.eu/jrc/en/gem-e3/model.

[36] Previously, and focusing also on energy intensive sectors, Welsch (2008) estimates elasticities for four European countries and 17 sectors with values ranging between 0.04 and 3.68.

[37] Németh et al. (2011) also report the trade elasticity between imports origination from two different countries (foreign-foreign) rather than between foreign and domestic (home-foreign) goods. These range between [0.8; 2.8].

that, compared to the above studies, the number of sectors for which trade elasticities exhibit the right sign and are statistically significant is greater in our case (all but the foreign elasticity of sector C20-22).

Moving up to the three sectors results presented in Table 6, we observe that the effect of considering the main categories is a reduction in the value of the parameters, and consequently, the macro-elasticities, ranging now from σ_F^C = 1.609 ('Manufacturing') to σ_F^B = 2.906 ('Mining and quarrying'). Therefore, considering more aggregate levels of commodities brings the value to the lower bound of the microelasticities. Again, we note that our aggregation strategy is done by reducing the number of dummy variables (and not aggregating the data within sectors), which prevents some known problems associated with the actual aggregation of the data, as discussed in Section 3.3. Most importantly, the macro elasticities obtained in such a way could misrepresent the actual reaction of consumers to relative price changes in domestic and foreign products.[38]

Altogether, we conclude that foreign trade elasticities are above those previously estimated for EU countries only, but in the range of those obtained in international studies, including countries of several world regions. This suggests that our analytical approach and detailed data does not exhibit the downward bias typically found for trade elasticities estimates at higher levels of aggregation (MacDaniel 2003, Imbs and Méjean 2015, Jovanovic 2013). Despite the differences in data and econometric approach, these results reinforce the conclusion that our elasticity estimates for comparable foreign trade flows, either at the micro or macro level, are quite robust, providing reassurance about our national elasticities that we comment next.

5.2.2. (Intra) national elasticities of trade

As for the second level of trade flows, (intra)national (or interregional) elasticities of trade are new to the literature. Our results indicate considerable variability across sectors. Besides the spread already presented and ranging between sector C20-22 (including 'Chemicals', C21, 'Pharmaceutical', C22, and 'Rubber products', C22): σ_N^{C20-22} = 1.843, and sector C25 ('Fabricated metal products'): σ_N^{C25} = 124.213, a minority of sectors (7 out of 14) exceed the value of 10. In this case, the median national trade elasticity is 10.106. Generally, as in the case of foreign elasticities, it is observed that the smaller elasticities correspond to

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[38] The same inequality between micro and macro elasticities is obtained by Aspelter (2016), who relying on the analytical framework by Feenstra et al. (2014), estimate their values for the 15 European Monetary Union (EMU) countries using panel data of trade flows for 2,692 product (manufacturing) categories over the period 1995-2012. In her case, from the perspective of consumers, micro elasticities refer to the elasticity of substitution between products imported from different countries and their aggregate (overall) value, while macro elasticities refer to the elasticity of substitution between these latter import aggregate and domestic production. Therefore, the two sets of trade elasticities are different in nature because hers do not differentiate foreign and (intra)national trade flows, which require data on trade flows at regional level. Her results, corresponding to a GMM estimation, have a (median) value ranging from 3 and 4 for the micro elasticities, and from 1 and 2 for macro elasticities.

sectors with relative low value added and/or producing relatively less differentiated varieties (or more homogenous products). Beyond the lowest value σ_N^{C20-2} = 1.843, sectors A01 ('Agriculture'), A02-A03 ('Products of forestry', A02, and 'Fishing', A03), B ('Mining and quarrying'), and C19 ('Coke and refined products') exhibit elasticities below 8. Only sector C31-32 (including 'Furniture', C31, and 'Other manufactured goods', C32) escapes this general characterization. On the contrary, values of trade elasticities above 10 correspond in general to sectors producing goods with higher value added and heterogeneous characteristics. Besides the largest value σ_N^{C25} = 134.035, sector C10-12 (including 'Food products', C10; 'Beverages', C11, and 'Tobacco', C12), all equipment related goods comprised in sector C26-28 ('Computer', C26, 'Electronic', C27, and 'Machinery', C28), sector C16-18 ('Wood', C17, 'Paper', C16, and 'Printing products', C17), as well as transport related products C30-31 ('Motor vehicles', C29, and 'Other transport equipment', C30), show elasticities above 20, thereby doubling the median and average elasticity of low value added and homogenous sectors.

This sectoral evaluation of the values of national trade elasticities applies directly to their (lower valued) foreign trade counterparts, since both series highly correlate: $\rho(\sigma_F^c, \sigma_N^c)$ = 0.965. Although counterintuitive, the fact that both foreign and national trade elasticities are lower for low-value added and homogenous goods and higher for high value added and heterogeneous goods is in line with the results reported in Olekseyuk and Schürenberg-Frosch (2016). An appealing explanation raised by these authors is that for some of these sectors the relative trade costs are very high or require special infrastructure investment. An example may be cement, which is a quite homogeneous product, but at the same time characterized by markets with a few very large players, high infrastructure investment requirements for handling and storage, long term contracts for leases of mines, etc.; all of which may cause importers to become locked in with specific suppliers over longer time periods, and prevents switching import origins even if prices change significantly. At the other end of the spectrum, cars or vehicles are quite heterogeneous, but at the same time transport costs are relatively low compared to the value of the product, there is no need for buyers to make specific investments for handling, and switching costs are almost non-existent, so it should not be surprising to see fast switching of import origin in presence of price changes.

Even if for the European case there are no precedents in the estimation of (intra)national elasticities of trade, Bilgic et al. (2002) have estimated national trade elasticities among US states and compared them to their international (foreign) counterparts (but without jointly estimating them as we do). To the extent that the US represents a single market area comparable to that of the UE, and therefore only transportation costs are available to identify elasticities, it is worth comparing our results with theirs.[39] Their estimates situate within the range [0.45; 2.80], and comparing them with those reported in the previous literature at the international level, they conclude that national elasticities and greater than international (foreign) elasticities, as it is also our case. However, because they do not set up a comprehensive three-level model that allows to jointly estimate foreign and national elasticities, the magnitudes in both sets of results are not directly comparable (nor can it be determined if their differences are statistically significant) because they are the result of comparing different data samples, time periods and econometric specifications.

As for the results of the national elasticities at the macro-levels, we observe once again that the aggregation process results in a significant reduction in their values. In particular, the elasticities range between the lowest value in σ_N^A = 4.573 ('Agriculture') and σ_N^B = 5.510 ('Mining and quarrying'). These values correspond to the estimates usually obtained in the empirical literature, based on the standard two-tier utility function as surveyed in Hillberry and Hummels (2013) for Trade Theory and requiring one single elasticity value. They also concur with the estimates reported in the Economic Geography literature, as surveyed by Head and Meyer (2004). Indeed, the values reported in Table 6 are those adopted in an array of studies from theoretical simulations of New Economic Geography, trade policy evaluations in New Trade Theory, to complex empirical regional CGE models. In all these domains the single elasticity parameter is normally assumed to be in the range between 4 and 5; e.g., see Fujita et al. (1999) for NEG models, Anderson and van Wincoop (2003) for NTT, and Lecca et al. (2018) for the RHOMOLO model of the European Commission. The fact that the national elasticities are those to be employed in regional modelling shows the importance of estimating them along with their foreign counterparts that capture trade elasticities between countries, and whose values are lower. The present study provides support to these choices by simultaneously estimating both levels of elasticities at both the micro and macro levels. To the best of our knowledge, this is the first time that such a comprehensive approach is explored and results are made available to researchers.

In general, from our results we confirm the hypothesis that national elasticities are greater than foreign elasticities based on the assumption that (intra)national trade is more sensitive to price variations than international trade because of higher substitutability. This result may be a consequence of the fact that intranational trade faces fewer non-price related trade restrictions than international trade (even within single markets like the EU), while, at the same time, the goods (varieties) produced in regions within the same country exhibit higher homogeneity. However, from the perspective of the product space and not geographical scope, we also obtain general evidence that, against previous assumptions, and using trade data to recover the values, sectors producing in general goods with

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[39] These authors also review estimates from seven US regional studies based on CGE models, all corresponding to gravity equations that are derived from a CES theoretical framework. The elasticities obtained in those studies for tradable goods sectors (i.e., excluding services) range between 1.5 and 3.5.

relatively low valued added and product differentiation exhibit lower elasticities of substitution and vice versa.

6. Conclusions

This study introduces the theory and practice allowing the estimation of two intertwined measures of import elasticity of substitution. Within the existing regional computable general equilibrium models (GCE), usually covering administrative units belonging to a common area characterized by a single market (e.g., the EU), it is possible to differentiate demand equations for domestically produced goods (i.e., within the same region), those imported from regions within the same country (interregional or national imports), and, finally, those sourced from regions situated in other countries (foreign or international imports). This gives rise to two levels of elasticities whose values have never been proposed theoretically, or jointly determined in an econometrically consisted way. Knowledge of the sensitivity of consumer to price changes in imports from closely located (national) regions or farther located (foreign) imports is critical for the correct calibration of regional CGE models and subsequent policy analyses. To the extent that these models disregard the reality behind these two levels of trade flows by adopting single-valued elasticities of trade, their results will be biased, thereby compromising the recommendations for trade policy. In particular, the welfare effects of trade (and transport) policies critically depend on their values. That is, regarding regional CGE modeling, from now on, there is no need to adopt single-valued elasticities drawn from the international trade literature, since it is possible to define and calculate both levels of elasticities.

We develop a three-tier theoretical model based on the CES utility function specification that provides the microeconomic foundation for the gravity equations from which these national and foreign elasticities of substitution can be identified. The equations are then econometrically estimated through the Poisson pseudo maximum likelihood (PPML) method using EU trade data. The theoretical model is consistent with the analytical framework of the RHOMOLO model curated by the Joint Research Center of the European Commission, while the datasets for the key and ancillary variables are obtained from existing databases. The reason is that full compatibility is required if this model is to benefit from our research by straightforwardly adopting the estimated values of trade elasticities in the necessary calibrations. However, we contend that these estimated elasticities can be useful to all sorts of RCGE models that routinely adopt values corresponding to international studies, and that cannot differentiate between the two levels of import substitutability.

A crucial issue regarding the data is the construction of a reliable transport cost measure, since this is the key variables from which the trade elasticities are recovered (as opposed to international trade models where tariffs serve to this purpose). We calculate a very detailed matrix of generalized transport costs between regions that accounts for the actual road infrastructure, optimal vehicle size depending on shipping distance, urban layout, and type of cargo. Coupled with information on average loads and unit prices, this allows us to calculate specific origin-destination ad valorem (iceberg) transportation costs. Such detailed methodology for calculating iceberg transport costs has never been brought into the national (interregional) and international trade literature related to the estimation of trade elasticities.

We explore alternative estimation strategies based on the traditional sector by sector (individual) estimation of both sets of elasticities as well as pooling the data by sectors to take advantage of larger sample sizes. The results from the individual estimations are unsatisfactory as the values for both sets of elasticities cannot be recovered in general. And for those sectors where it can, in many sectors we cannot reject the hypothesis that national and foreign trade elasticities are equal. These results are overcome by adopting the pooled regression, as all elasticities exhibit the predicted sign, sensible magnitudes and, more importantly, are statistically significant. In the most reliable specification the median value for the national trade elasticities is 10.1, while those for foreign trade elasticity drops to 4.6. Consequently, from our research, we conclude that national trade elasticities double in general the magnitude of their foreign counterparts.

Based on these results, we support the existing rule of thumb for studies where both elasticities are not available. This finding constitutes the first empirical confirmation of the hypothesis that national trade elasticities of import substitution ought to be larger than their foreign counterparts because consumers find it easier to substitute goods sourced from nearby regions within the same country, as they are better informed about the price and characteristics of relatively similar products, than if they are imported from abroad for which close substitutes are difficult to find. We also provide estimates of both sets of variables to higher levels of industry data. When we run the same regression but considering only the three main categories of tradable goods: agriculture, mining and manufacturing. We find that for those aggregates for which subcategories exist, national trade elasticities decrease. This is particularly acute in the manufacturing sector, whose values are about a third of the median value of the 10 individual sectors that it comprises: 4.846 vs. 13.723. The same differences resulting in lower values are observed for the foreign trade elasticities. Finally, the values of our single national and foreign trade elasticities, standing at 4.652 and 2.156, are similar to those reported in the existing literature, which gives credibility to our lower level results. In general, we confirm that the level of data aggregation by industry categories is not neutral. On the other hand, contrary to what would be expected, we do not find that sectors with relatively low valued added and product differentiation exhibit higher trade elasticities of substitution. Looking at the relation between trade flows and transportation costs, we observe that this result can be explained by the fact that for these sectors trade flows are less sensitive to transportation costs, perhaps because they constitute intermediate products that demanded across the whole European Union as suggested in the literature. This represents a further line of research.

We conclude encouraging researchers involved in regional GCE modeling with different spatial levels of trade flows and transportation costs to study the present proposal and explore the need to differentiate between national and foreign trade elasticities. To the extent that the magnitudes and differences between the two are statistically significant, an important feature of the trade flows between regions would be missing. Adopting theoretical frameworks where this reality is overlooked could seriously compromise the reliability of the models and our confidence in the policy recommendations derived from them. To address this void, we provide the modeling tools and econometric methods that enable the implementation of the current proposal, which should prove useful in the theory and practice of regional GCE modeling by improving the characterization of consumers' behavior with respect to national and foreign goods, while emphasizing the need for a careful calculation of transport costs. Future research will address how the methodological improvements that we propose alter the results obtained from alternative policy experiments within the current and our newly analytical framework. One key experiment would be the determination of the effects of infrastructure investments (bringing larger reductions in transport costs for developing regions), on regional trade, gross domestic product and, ultimately, social welfare.

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Appendices

Appendix 1. Correspondence table between the CPA 2.1 and NST 2007 classifications

CPA 2.1	NST 2007	Description CPA 2.1
CPA_A01	01	Products of agriculture hunting and related services
CPA_A02_A03	01	Products of forestry, logging and related services. Fish and other fishing products, aquacult. Products, support services to fish.
CPA_B	02-03	Mining and quarrying
CPA_C10-C12	04	Food products beverages and tobacco products
CPA_C13-C14-C15	05	Textiles wearing apparel and leather products
CPA_C16-C17-C18	06	Wood and products of wood and cork except furniture, articles of straw … Paper and paper products. Printing and recording services
CPA_C19	07	Coke and refined petroleum products
CPA_C20-C21-C22	08	Chemicals and chemical products. Basic pharmaceutical products and pharmaceutical preparations. Rubber and plastics products
CPA_C23	09	Other non-metallic mineral products
CPA_C24	10	Basic metals
CPA_C25	10	Fabricated metal products except machinery and equipment
CPA_C26-C27-C28	11	Computer electronic and optical products. Electrical equipment. Machinery and equipment nec
CPA_C29-C30	12	Motor vehicles trailers and semi-trailers. Other transport equipment
CPA_C31-C32	13	Furniture and other manufactured goods

Note: The correspondence tables between the two classifications is presented at the Eurostat's RAMON site: https://ec.europa.eu/eurostat/ramon/relations/index.cfm?TargetUrl=LST_REL&StrLanguageCode=EN&IntCurrentPage=11

Appendix 2. Economic cost factors for selected vehicles depending on size.

Economic costs	Vehicle HDV (5 axles) Large	 Rigid (3 axles) Medium	 Small (2 axles) Small
Variable costs			
Distance			
Fuel	1.000	0.611	0.317
Tire	1.000	0.911	1.041
Maintenance	1.000	1.282	1.121
Time			
Labor	1.000	1.000	1.000
Amort&Fin	1.000	0.626	0.296
Insurance	1.000	0.715	0.623
Indirect	1.000	0.571	0.445
Fixed costs			
Handling	1.000	0.752	0.309
Tax	1.000	0.910	0.849
Vignette	1.000	0.600	0.600

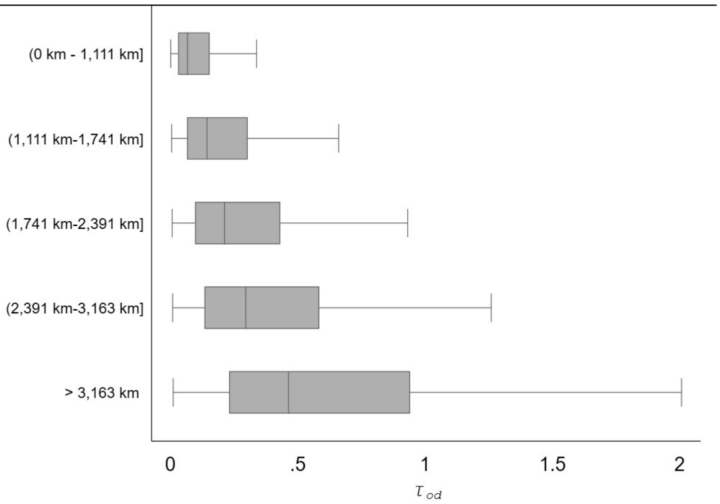
Note: The standard Heavy Duty Vehicle (HDV) costs reported in Persyn et al. (2020), corresponding to a 40 ton articulated truck, are the baseline for the remaining vehicles.

Appendix 3. Economic costs factors for selected vehicles depending on cargo

Costs	Standard HDV	Liquid/Solid Bulk Food	Liquid/Solid Tanker Dangerous	Tanker Gas	Liquid/Solid Bulk	Carrier vehicles	Container (Skeletal)
Variable	1.000	1.313	1.270	2.226	1.345	1.222	0.997
Tax	1.073	1.173	1.163	1.058	1.142	0.893	1.073
Vignette	1.087	1.150	1.797	1.000	1.190	1.000	1.087
Handling	1.000	1.000	1.000	1.000	0.000	1.000	1.000

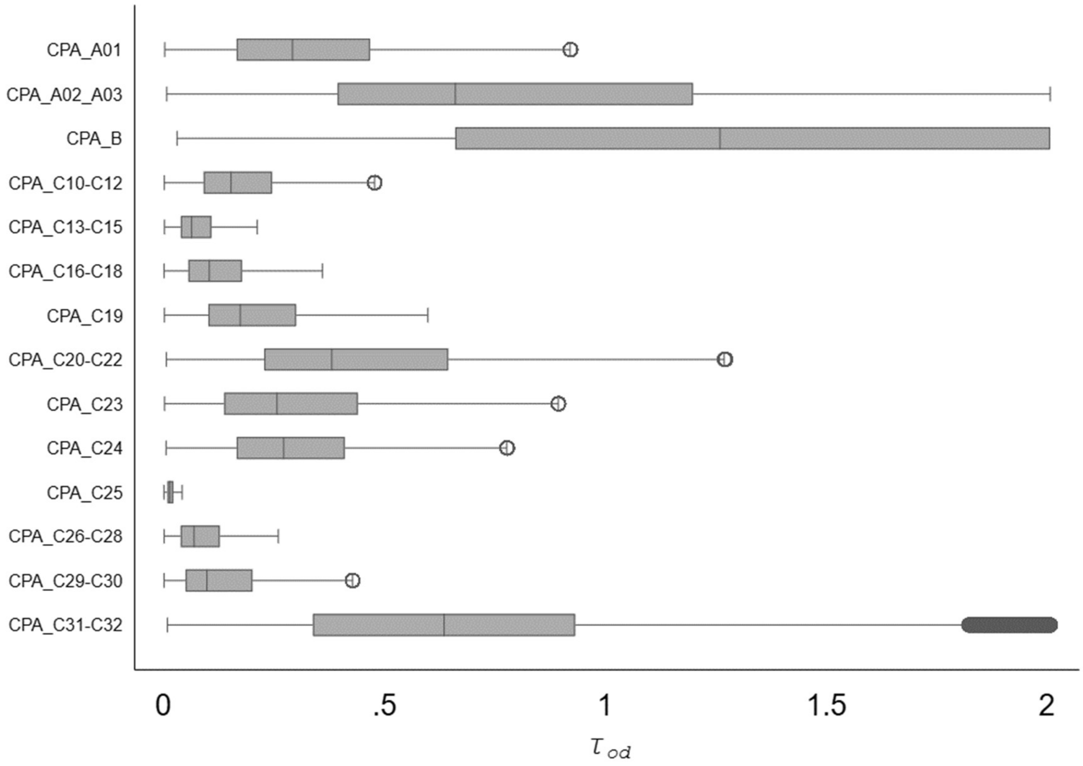
Source: Own elaboration based on Zofío et al (2014) and MFOM(2018).

Appendix 4. Iceberg, generalized transport costs and units prices *by quintiles of* GTC_{od}^{c}

Variable / GTC_{od}^{c}	$\overline{\tau}_{od}^{c}$	$\overline{GTC}_{od}^{c}$	$\overline{P}_{od}^{c}$	
(0 km–1,111 km]	0.111	689	1,438	
(1,111 km–1,741 km]	0.222	1,428	1,484	
(1,741 km–2,391 km]	0.319	2,060	1,449	
(2, 391 km–3,163 km]	0.435	2,752	1,386	
> 3,163 km	0.735	4,096	1,183	

Notes: Average variables. Source: Own elaboration.

Appendix 5. Distributions of iceberg transport costs by sector, τ_{od}^{c} .



Source: Own elaboration.

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