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TRADE COSTS IN THE GLOBAL ECONOMY: MEASUREMENT, AGGREGATION AND DECOMPOSITION*

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Abstract: Proper measurement and aggregation of trade costs is of paramount importance for sound academic and policy analysis of the determinants – particularly those of policy – of economic outcomes. The international trade profession has witnessed significant new developments, both on the theoretical and on the empirical side, concerning the measurement and decomposition of such costs into variable and fixed costs on the one hand and into partial and general equilibrium effects on the other hand. The objectives and main contributions of this project are to offer guidance for proper measurement, aggregation, and decomposition of trade costs into fixed vs. variable and partial vs. general equilibrium costs across two broad dimensions, one including overall trade costs vs. policy measures vs. transportation costs vs. natural trade barriers vs. uncertainty and another one including geography vs. product vs. household income level vs. agent.

Key Words: Trade costs; Structural gravity; Multi-sector and multi-country models; Heterogeneous firms; Panel data; Measurement; Aggregation; Decomposition.

JEL Classification: C23; C31; F1

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1 Introduction: Motivation and Executive Summary

Proper quantification, aggregation and decomposition of trade costs costs – capturing any variable and fixed access costs, costs to cross-border (international) and domestic transactions, discriminatory versus non-discriminatory "precautionary" policies and associated costs, as well as the partial and general equilibrium effects of such costs – is of paramount importance for sound academic and policy analysis of domestic versus international sales and trade flows and for proper quantification of the impact of regional, national, and international policies on various outcomes of open economies. The international trade profession has witnessed significant new developments both on the theoretical and on the empirical side of the literature towards an assessment of such costs, including:

- New decompositions and associated measurement of trade costs into their fixed and variable components through the prism of the firm heterogeneity literature (see for example Melitz, 2003; Das, Roberts and Tybout, 2007; Helpman, Melitz and Rubinstein, 2008; Chaney, 2008).

- New forms and measurement of non-discriminatory, "precautionary" sales and trade policies such as sanitary and phytosanitary (SPS) and technical barriers to trade (TBT), which complemented – and largely replaced – traditional forms of "protectionist" barriers to cross-border trade such as tariffs and quotas (see for example Berden et al., 2009; Berden and Francois, 2015; Egger et al., 2015; Lamy, 2015).

- New emphasis on and measurement of domestic (or intra-national) transaction costs and their importance for proper measurement and interpretation of international trade barriers and welfare analysis (see for example Agnosteva, Anderson and Yotov, 2014; Atkin and Donaldson, 2015; Anderson and Yotov, 2016; Coşar and Fajgelbaum, 2016; Donaldson, 2016; Ramondo, RodrÃguez-Clare and SaborÃo-RodrÃguez, 2016; Tombe and Winter, 2016).

- New empirical methods to estimate, calibrate, and reconcile the estimation and calibration approaches towards quantifying (mostly variable) trade and transaction costs (see for example Balistreri and Hillberry, 2005; Anderson, Larch and Yotov, 2015; Egger and Nigai, 2015).

- New theoretical methods that emphasize the importance of trade and transaction costs and their proper use to quantify the impact of trade policies and other trade cost changes (see for example Arkolakis, Costinot and RodrÃguez-Clare, 2012; Anderson and Yotov, 2010; Dekle, Eaton and Kortum, 2007, 2008; Chaney, 2016).

- New databases (measuring trade, production, and protection) which allow for the assessment of new theoretical and an implementation of new quantitative methods, and also generate new stylized facts. Some examples include the World-Input-Output database (WIOD) of sectoral trade and production with input-output linkages and the WTO's I-TIP database, which offers data on a series of non-tariff measures (NTMs) (see Yotov et al., 2016, for a recent survey of relevant data).

The broad objectives and main contributions of this project are to offer guidance for proper measurement, aggregation, and decomposition of trade costs into fixed vs. variable and partial vs. general equilibrium (GE) costs across two broad dimensions including a vertical dimension (e.g., overall trade costs vs. policy measures vs. transportation costs vs. natural trade barriers vs. uncertainty) and a horizontal dimension (e.g., geography vs. product vs. household income level vs. agent). In order to achieve these goals, we develop the project in several interrelated stages.

- Section 2 capitalizes and extends on the latest advances in the structural gravity literature to develop a generic structural trade model by synthesizing some of the major developments in the related literature, which enable us to distinguish between the different trade components and which will guide the empirical analysis. Specifically, our goals are to develop and present a model, which (i) enables a decomposition of trade costs into their variable vs. fixed cost components, (ii) allows for a clear decomposition of trade costs into their partial vs. general equilibrium vs. total components, and (iii) develops theory-consistent methods for trade cost aggregation across various dimensions, e.g., across regions and across sectors both at the partial and at the GE level.

- Proper measurement of the direct bilateral trade costs is at the heart of any trade cost and trade-policy analysis, and it is one of the primary objectives of this project. Accordingly, the goal of Section 3 is to develop and present methods for identification and decomposition of bilateral trade costs. In order to achieve this goal we start with a brief presentation of the leading methods to measure bilateral trade costs, including estimation vs. calibration vs. calculation, and we discuss their advantages and disadvantages. Based on this discussion, and given that one of the main objectives of this project is to decompose trade costs into their key components, we will develop and rely mostly on parametric techniques. However, we propose and employ a hybrid procedure to construct bilateral trade costs, which combines the most appealing features of the "estimation" and the "calibration" approaches. The approach first estimates total barriers to trade and trade elasticities from a properly specified empirical gravity equation based on the generic structural trade model that we developed in Section 2. Then trade costs are decomposed into various components. As a result, our approach delivers estimates of variable and fixed trade costs, which, subject to data availability, allow for a decomposition of their key components and enables us to recover key response parameters, while at the same time fitting the aggregate producer-to-consumer sales data.

- Section 4 presents our data and describes the data sources and potential caveats with regard to the data. In order to perform the main empirical analysis, we will use the World-Input-Output-Tables (WIOD), which covers 41 countries and an aggregate rest-of-the-world region for the period from 1996 to 2011. The sectoral coverage of WIOD includes 35 sectors, of which 16 sectors can be classified as manufacturing. Several advantages of the WIOD database make it particularly appropriate for our analysis. First, the WIOD data include consistently constructed domestic sales (i.e., internal or domestic trade). Second, the WIOD data offer a comprehensive sectoral coverage, which adds to the total sales and production for each country in the database. This will enable us to aggregate our sectoral indexes in order to construct consistent trade costs at the country level. Third, the WIOD data can be combined with the Socio Economic Accounts database, which will enable us to construct unit costs that are needed for the structural analysis. In addition to the WIOD data of trade and production, we will use a series of other datasets which will enable us to measure and decompose trade costs into various components. Possible databases include the WTO's I-TIP database, which offers data on a series of NTM measures and stretches back to 1996, and the CEPII database, which includes data on a number of standard determinants of trade costs.

- Section 5 begins with a presentation and a discussion of the key structural parameters in our model. Next, we obtain and discuss our measures of bilateral trade costs, which are decomposed into the two key dimensions of interest, i.e., variable vs. fixed trade costs. We decompose variable and fixed trade costs by countries, sectors, and years. We also conduct decompositions of trade costs across three important dimensions. First, we calculate average trade costs for different consumers depending on the level of income. We find that richer consumers generally face higher variable and fixed trade costs. Second, we also decompose the trade costs by the skill levels of employed labor. It turns out, that workers with medium skills face relatively higher trade costs in exporting. Finally, even though we do not use firm-level trade data for the analysis, we use back-of-the envelop calculations to decompose our measures of bilateral trade barriers according to firm-size groups. We find that while larger firms generally face lower variable trade costs, they have higher fixed trade costs.

Then, we construct total trade cost indexes and analyze their behavior across the main dimensions of our sample, including countries, sectors, and years to conclude the following: (i) Total Trade Costs (TTCs) are large; (ii) TTCs are very heterogeneous across countries; (iii) TTCs are relatively symmetric on the exporter vs. the importer side with some exceptions; (iv) TTCs have become more symmetric over time; (v) TTCs have steadily fallen over time on average; (vi) the change in TTCs has been non-monotonic, clearly reflecting global recessions; (vii) the change in TTCs over time is heterogeneous across countries; (viii) finally, we offer a detailed analysis of the TTCs across the sectors in our sample and we document significant heterogeneity across sectors in terms of levels as well as in terms of evolution over time. The last two subsections of Section 5 offer an analysis of the general equilibrium trade cost component of TTCs as well as a decomposition of trade costs by economic agent based on the skill level of workers in production. With respect to general equilibrium trade costs, we find that those are large and that they vary significantly across sectors. With respect to the decomposition of trade costs across skill groups, we document the intuitive result that skilled workers are the ones to bear most of the trade costs in skilled-abundant nations, while unskilled labor bears most of the trade costs in countries that are abundant in unskilled workers.

2 Theoretical Foundations

The objective of this section is to develop a generic structural trade model which synthesizes the latest developments in the related literature and which will guide the empirical analysis. Specifically, our goals are to develop and present a model which (i) enables a decomposition of trade costs into their variable vs. fixed cost components, (ii) allows for a decomposition of trade costs into their partial vs. GE components, and (iii) develops theory-consistent methods for trade cost aggregation across various dimensions, e.g., across regions and across sectors. To that end, we capitalize on the latest developments in the structural gravity literature.

Owing to its intuitive appeal, solid theoretical foundations, and remarkable predictive power, the gravity model of trade has become the workhorse model in international trade to quantify trade costs. Stimulated by the early success and influence of the most prominent structural gravity models of Eaton and Kortum (2002) and Anderson and van Wincoop (2003), Anderson and van Wincoop (2004) relied on the theoretical gravity model in order to guide their analysis of variable trade costs, which has become one of the most cited and influential works in the trade literature. More recently, Arkolakis, Costinot and RodrÃguez-Clare (2012) demonstrate that the structural gravity model of trade is representative of a quite wide class of trade models.[2] Our analysis of trade costs will build on the latest developments in the structural gravity literature and will improve on the original trade costs analysis of Anderson and van Wincoop (2004) in several directions. Most notably, in relation to previous work, we use the structural model background to quantify and emphasize the importance of not only variable costs – as is customary in the literature – but also of fixed costs and domestic and international market access costs. The empirical analysis of market access costs here will be guided by economic theory, which we develop next.

2.1 A Generic Structural Trade Model

We consider a world of J countries, where agents produce in and consume from S sectors during T periods towards postulating a generic version of a multi-country and multi-sector

[2] Anderson (1979) is the first to derive a theoretical gravity equation of trade in an Armington (1969)–CES setting. Krugman (1980) and Bergstrand (1985) derive gravity with monopolistic competition. Deardorff (1998) obtains gravity in a Heckscher-Ohlin framework, while Eaton and Kortum (2002) and Costinot, Donaldson and Komunjer (2012) derive it in a Ricardian model with intermediates. Most recently, Chaney (2008) and Helpman, Melitz and Rubinstein (2008) derive a gravity model in a setting with heterogeneous firms and selection into markets. See Leamer and Levinsohn (1995) for an early survey of the gravity literature, Anderson (2011), Arkolakis, Costinot and RodrÃguez-Clare (2012), Bergstrand and Egger (2010), Bergstrand and Egger (2011), Head and Mayer (2014), Costinot and RodrÃguez-Clare (2014), and Yotov et al. (2016) for more recent surveys of the evolution of the theoretical gravity literature.

model of international trade with heterogeneous firms featuring both variable and fixed trade costs. We will generally index countries, sectors, and time periods by $\{i, j\}$, $\{r, s\}$, and t and denote the corresponding sets by $\mathfrak{J}$, $\mathfrak{S}$, and $\mathfrak{T}$, respectively.

Akin to Caliendo and Parro (2015), we portray sectors as to be linked by an international input-output structure. Hence, with J countries and S sectors there is a $JS \times JS$ world input-output matrix in any specific time period. Firms of any country i and sector s supply products as intermediates to other firms which belong in one of the cells of this $JS \times JS$ world input-output matrix.

Specifically, we assume a customary CES demand structure about individual, differentiated varieties. Each variety is uniquely supplied by a single firm and indexed by ϕ, which also indexes and corresponds to the respective firm's productivity level. As firms are unique sellers of their variety, they have market power. Regarding the latter, we assume that they are monopolistically competitive and produce under increasing returns to scale due to fixed costs. The degree of competitiveness in a sector is governed by the sector-specific elasticity of substitution among the varieties, σ^s. At time t, firms in country i and sector s involve (a bundle of) factors for production at variable costs per efficiency unit, $c^s_{i,t}$. When knowing a firm's productivity, marginal factor costs per efficiency unit, and (constant) markup over marginal costs, $\sigma^s/(\sigma^s - 1)$, we know its mill price per unit of output (i.e., the unit value) under these assumptions:[3]

$$p^s_{i,t}(\phi) \quad = \quad \frac{\sigma^s}{\sigma^s - 1}\frac{c^s_{i,t}}{\phi}. \tag{1}$$

However, the mill price is only partly relevant for customers. What matters as well are (variable) trade costs and (fixed) market-access costs. Regarding the former, we assume a customary iceberg, ad valorem structure, whereby the price charged to a customer in market

[3]Note that the assumption of a constant elasticity of substitution is customary in quantitative work, but it brings about some limitations. See Neary (2016) and Mrázová and Neary (2017) for a discussion of a departure from these assumptions.

j – irrespective of the sector affiliation of that customer – amounts to:

$$p^s_{ij,t}(\phi) \;\; = \;\; p^s_{i,t}(\phi)\tau^s_{ij,t}b^s_{ij,t}, \tag{2}$$

where $\tau^s_{ij,t}b^s_{ij,t} \geq 1$ is the iceberg factor – $\tau^s_{ij,t} \geq 1$ pertaining to non-tariff (e.g., transport) ad-valorem trade costs and $b^s_{ij,t} \geq 1$ to ad-valorem tariffs. Regarding fixed market-access costs, we assume that they are indexed akin to variable trade costs, whereby firms in country i and sector s have to use domestic factors in the same way of bundling as for production to generate market access to country j. We denote the associated (values) fixed market access costs by $c^s_{i,t}f^s_{ij,t}$.[4]

Firms in country j and sector r purchase inputs from all countries and sectors. We denote the aggregate expenditures of these firms in j and r at time t by $E^r_{j,t}$. The aggregate price index at which each and everyone of those firms buys all varieties supplied to its market be denoted by $P^r_{j,t}$ (we will define it as a scaled ideal price index below). Armed with this notation, we may define the revenues of a firm with productivity ϕ (including tariffs), which is located in i and operates in s, from serving firms in country j and sector r at time t as:

$$x^{sr}_{ij,t}(\phi) = \left(\frac{\sigma^s}{\sigma^s - 1} \frac{c^s_{i,t}\tau^s_{ij,t}b^s_{ij,t}}{\phi P^r_{j,t}} \right)^{1-\sigma^s} E^r_{j,t}. \tag{3}$$

The profits associated with these revenues (excluding tariffs) are:

$$\pi^{sr}_{ij,t}(\phi) = \frac{(b^s_{ij,t})^{-\sigma^s}}{\sigma^s} \left(\frac{c^s_{i,t}\tau^s_{ij,t}}{\phi P^r_{j,t}} \right)^{1-\sigma^s} E^r_{j,t} - c^s_{i,t}f^s_{ij,t}. \tag{4}$$

Due to the indexation of sales and profits, there is a (unique) productivity cut-off level, which is specific to country pair $\{ij\}$, sector tuple $\{sr\}$, and time period t at which the respective

[4]We generally adhere to the customary assumption that prices are multiplicative in trade costs, known as the iceberg-trade-cost assumption. We refer the reader to Irarrazabal, Moxnes and Opromolla (2015) for a less straightforward approach with additive trade costs.

firm in i and s is indifferent between selling output to customers in j and r at time t or not:

$$\phi_{ij,t}^{sr} = A^s \tau_{ij,t}^s \left(c_{i,t}^s b_{ij,t}^s\right)^{\frac{\sigma^s}{\sigma^s-1}} (P_{j,t}^r)^{-1} (E_{j,t}^r)^{\frac{1}{1-\sigma^s}} (f_{ij,t}^s)^{\frac{1}{\sigma^s-1}}, \tag{5}$$

where A^s is a constant.

Given $\phi_{ij,t}^{sr}$ as the floor of the distribution of ϕ with regard to firms in county i and sector s that sell to country j and sector r at time t, we can calculate the aggregate sales (including tariffs) by integrating over all firms as:

$$X_{ij,t}^{sr} = B^s N_{i,t}^s \left(c_{i,t}^s \tau_{ij,t}^s b_{ij,t}^s\right)^{1-\sigma^s} (P_{j,t}^r)^{\sigma^s-1} E_{j,t}^r \int_{\phi_{ij}^{sr}}^{\infty} \phi^{\sigma^s-1} g_i^s(\phi) d\phi, \tag{6}$$

where B^s is a constant, $N_{i,t}^s$ is the number of operating firms in country i and sector s at time t, and $g_i^s(\phi)$ is the probability density function (p.d.f.) of productivity parameters of firms in country i and sector s. Note that zero trade flows, $X_{ij,t}^{sr} = 0$ would only emerge in the extreme case of infinitely high variable or fixed trade costs, here. However, according to the data that we will use below, zero bilateral trade flows at the level of sectoral aggregation which we will use are unlikely/not important.

In order to obtain a log-linear specification of $X_{ij,t}^{sr}$, we assume the following Pareto p.d.f. for the distribution of ϕ:[5]

$$g_i^s(\phi) = \theta^s h_i^s \phi^{-\theta^s-1}. \tag{7}$$

Under this assumption, we can rewrite the equation for trade flows as (see for a detailed

[5]The assumption about Pareto-distributed productivity greatly simplifies the analysis and is an important approximation when adopting a macroeconomic approach to estimating trade elasticities. Earlier research suggests that the Pareto distribution is only an approximation. Some authors suggested that the Lognormal distribution is better supported by the data than the Pareto distribution (see Head, Mayer and Thoenig, 2014), that a mixture of the Pareto and the Lognormal is preferable (see Nigai, 2017), or that micro data reject any parametric approximation of the actual distribution (see Egger, Erhardt and Nigai, 2020). However, in absence of microdata, the Pareto assumption still serves as a useful approximation to the data.

derivation Appendix A):

$$X_{ij,t}^{sr} = C^s N_{i,t}^s h_i^s c_{i,t}^s b_{ij,t}^s f_{ij,t}^s (\phi_{ij}^{sr})^{-\theta^s}, \tag{8}$$

where C^s is a constant. If we substitute the explicit expression for ϕ_{ij}^{sr} in (8) and divide by $E_{j,t}^r$, we obtain the following expression for aggregate expenditure shares of firms in j and r on output of firms in i and s at time t (including tariffs):

$$\lambda_{ij,t}^{sr} = \frac{X_{ij,t}^{sr}}{E_{j,t}^r} = D^s N_{i,t}^s h_i^s (c_{i,t}^s)^{1-\frac{\theta^s\sigma^s}{\sigma^s-1}} (\tau_{ij,t}^s)^{-\theta^s} \left(b_{ij,t}^s\right)^{1-\frac{\theta^s\sigma^s}{\sigma^s-1}} (f_{ij,t}^s)^{1-\frac{\theta^s}{\sigma^s-1}} (P_{j,t}^r)^{\theta^s} (E_{j,t}^r)^{\frac{\theta^s-(\sigma^s-1)}{\sigma^s-1}}. \tag{9}$$

where D^s is some constant.[6] We will generally assume and impose that $\theta^s > \sigma^s - 1$.

We next transform our model into a structural gravity system that more closely resembles the structural gravity models of Eaton and Kortum (2002) and Anderson and van Wincoop (2003). There are several benefits from this effort. First, this presentation of our model will enable us to emphasize the fact that our generic model is representative of and extends to a wide class of structural gravity models, while at the same time we will be able to emphasize key modeling features. Second, this will allow us to clearly decompose size vs. cost components of the gravity equation as well as to decompose trade costs into partial vs. GE vs. total costs. Third, the generalized presentation of the structural gravity system will facilitate the discussion and development of the procedures for aggregating trade costs, which we present in the next section.

Start with equation 9 written in levels:

$$X_{ij,t}^{sr} = D^s N_{i,t}^s h_i^s (c_{i,t}^s)^{1-\frac{\theta^s\sigma^s}{\sigma^s-1}} (\tau_{ij,t}^s)^{-\theta^s} (b_{ij,t}^s)^{1-\frac{\theta^s\sigma^s}{\sigma^s-1}} (f_{ij,t}^s)^{1-\frac{\theta^s}{\sigma^s-1}} (P_{j,t}^r)^{\theta^s} (E_{j,t}^r)^{\frac{\theta^s}{\sigma^s-1}}. \tag{10}$$

[6] Note that $\tau_{ij,t}^s$ and $b_{ij,t}^s$ do not have the same exponent. This is due to the fact that tariffs are applied to sales revenues rather than costs. In the latter case, $\tau_{ij,t}^s$ and $b_{ij,t}^s$ would have the same exponent. However, we find that assumption less plausible.

Impose market clearance at delivered prices, whereby total production of i at time t in sector s, $Y_{i,t}^{s}$, has to equal total sales to all sectors r and all countries j at time t, i.e., $Y_{i,t}^{s} = \sum_j \sum_r X_{ij,t}^{sr}$:

$$\begin{aligned} Y_{i,t}^{s} &= \sum_j \sum_r D^s N_{i,t}^{s} h_i^s (c_{i,t}^{s})^{1-\frac{\theta^s \sigma^s}{\sigma^s - 1}} (\tau_{ij,t}^{s})^{-\theta^s} (b_{ij,t}^{s})^{1-\frac{\theta^s \sigma^s}{\sigma^s - 1}} (f_{ij,t}^{s})^{1-\frac{\theta^s}{\sigma^s - 1}} (P_{j,t}^{r})^{\theta^s} (E_{j,t}^{r})^{\frac{\theta^s}{\sigma^s - 1}} \\ &= D^s N_{i,t}^{s} h_i^s (c_{i,t}^{s})^{1-\frac{\theta^s \sigma^s}{\sigma^s - 1}} \sum_j \sum_r (\tau_{ij,t}^{s})^{-\theta^s} (b_{ij,t}^{s})^{1-\frac{\theta^s \sigma^s}{\sigma^s - 1}} (f_{ij,t}^{s})^{1-\frac{\theta^s}{\sigma^s - 1}} (P_{j,t}^{r})^{\theta^s} (E_{j,t}^{r})^{\frac{\theta^s}{\sigma^s - 1}}. \end{aligned}$$

Solve the previous equation for $D^s N_{i,t}^{s} h_i^s (c_{i,t}^{s})^{1-\frac{\theta^s \sigma^s}{\sigma^s - 1}}$ to obtain:

$$D^s N_{i,t}^{s} h_i^s (c_{i,t}^{s})^{1-\frac{\theta^s \sigma^s}{\sigma^s - 1}} = \frac{Y_{i,t}^{s}}{\sum_j \sum_r (\tau_{ij,t}^{s})^{-\theta^s} (b_{ij,t}^{s})^{1-\frac{\theta^s \sigma^s}{\sigma^s - 1}} (f_{ij,t}^{s})^{1-\frac{\theta^s}{\sigma^s - 1}} (P_{j,t}^{r})^{\theta^s} (E_{j,t}^{r})^{\frac{\theta^s}{\sigma^s - 1}}}. \tag{11}$$

Replace the expression for $D^s N_{i,t}^{s} h_i^s (c_{i,t}^{s})^{1-\frac{\theta^s \sigma^s}{\sigma^s - 1}}$ in equation (10):

$$X_{ij,t}^{sr} = \frac{(\tau_{ij,t}^{s})^{-\theta^s} (b_{ij,t}^{s})^{1-\frac{\theta^s \sigma^s}{\sigma^s - 1}} (f_{ij,t}^{s})^{1-\frac{\theta^s}{\sigma^s - 1}} (P_{j,t}^{r})^{\theta^s} (E_{j,t}^{r})^{\frac{\theta^s}{\sigma^s - 1}} Y_{i,t}^{s}}{\sum_j \sum_r (\tau_{ij,t}^{s})^{-\theta^s} (b_{ij,t}^{s})^{1-\frac{\theta^s \sigma^s}{\sigma^s - 1}} (f_{ij,t}^{s})^{1-\frac{\theta^s}{\sigma^s - 1}} (P_{j,t}^{r})^{\theta^s} (E_{j,t}^{r})^{\frac{\theta^s}{\sigma^s - 1}}}. \tag{12}$$

Define:

$$(\Pi_{i,t}^{s})^{-\theta^s} \equiv \sum_j \sum_r (\tau_{ij,t}^{s})^{-\theta^s} (b_{ij,t}^{s})^{1-\frac{\theta^s \sigma^s}{\sigma^s - 1}} (f_{ij,t}^{s})^{1-\frac{\theta^s}{\sigma^s - 1}} (P_{j,t}^{r})^{\theta^s} (E_{j,t}^{r})^{\frac{\theta^s}{\sigma^s - 1}}. \tag{13}$$

Then replace this definition in equation (12) to obtain:

$$X_{ij,t}^{sr} = (\tau_{ij,t}^{s})^{-\theta^s} (b_{ij,t}^{s})^{1-\frac{\theta^s \sigma^s}{\sigma^s - 1}} (f_{ij,t}^{s})^{1-\frac{\theta^s}{\sigma^s - 1}} (\Pi_{i,t}^{s})^{\theta^s} (P_{j,t}^{r})^{\theta^s} (E_{j,t}^{r})^{\frac{\theta^s}{\sigma^s - 1}} Y_{i,t}^{s}. \tag{14}$$

The price index is given by (see for a detailed derivation Appendix B):

$$(P_{j,t}^{r})^{-\theta^s} = \sum_i \sum_s (b_{ij,t}^{s})^{1-\frac{\sigma^s \theta^s}{\sigma^s - 1}} (\tau_{ij,t}^{s})^{-\theta^s} (f_{ij,t}^{s})^{1-\frac{\theta^s}{\sigma^s - 1}} (E_{j,t}^{r})^{\frac{\theta^s}{\sigma^s - 1} - 1} (\Pi_{i,t}^{s})^{\theta^s} Y_{i,t}^{s}.$$

Rearrange terms and add world output in sector s, Y_t^s, to obtain:

$$(P_{j,t}^r)^{-\theta^s} = (E_{j,t}^r)^{\frac{\theta^s}{\sigma^s-1}-1} Y_t^s \sum_i \sum_s (\tau_{ij,t}^s)^{-\theta^s} (b_{ij,t}^s)^{1-\frac{\theta^s\sigma^s}{\sigma^s-1}} (f_{ij,t}^s)^{1-\frac{\theta^s}{\sigma^s-1}} (\Pi_{i,t}^s)^{\theta^s} \frac{Y_{i,t}^s}{Y_t^s}. \tag{15}$$

Define:

$$(\tilde{P}_{j,t}^r)^{-\theta^s} \equiv \sum_i \sum_s (\tau_{ij,t}^s)^{-\theta^s} (b_{ij,t}^s)^{1-\frac{\theta^s\sigma^s}{\sigma^s-1}} (f_{ij,t}^s)^{1-\frac{\theta^s}{\sigma^s-1}} (\Pi_{i,t}^s)^{\theta^s} \frac{Y_{i,t}^s}{Y_t^s}. \tag{16}$$

Replace the definition of $(\tilde{P}_{j,t}^r)^{-\theta^s}$ in equation (15) and rearrange to obtain:

$$(\tilde{P}_{j,t}^r)^{\theta^s} \frac{E_{j,t}^r}{Y_t^s} = (P_{j,t}^r)^{\theta^s} (E_{j,t}^r)^{\frac{\theta^s}{\sigma^s-1}}. \tag{17}$$

Use (17) to replace for the definition of $(P_{j,t}^r)^{\theta^s} (E_{j,t}^r)^{\frac{\theta^s}{\sigma^s-1}}$ in equation (12) and in equation (13), respectively, to obtain:

$$X_{ij,t}^{sr} = (\tau_{ij,t}^s)^{-\theta^s} (b_{ij,t}^s)^{1-\frac{\theta^s\sigma^s}{\sigma^s-1}} (f_{ij,t}^s)^{1-\frac{\theta^s}{\sigma^s-1}} (\Pi_{i,t}^s)^{\theta^s} (\tilde{P}_{j,t}^r)^{\theta^s} \frac{E_{j,t}^r Y_{i,t}^s}{Y_t^s}, \tag{18}$$

and

$$(\Pi_{i,t}^s)^{-\theta^s} \equiv \sum_j \sum_r (\tau_{ij,t}^s)^{-\theta^s} (b_{ij,t}^s)^{1-\frac{\theta^s\sigma^s}{\sigma^s-1}} (f_{ij,t}^s)^{1-\frac{\theta^s}{\sigma^s-1}} (\tilde{P}_{j,t}^r)^{\theta^s} \frac{E_{j,t}^r}{Y_t^s}. \tag{19}$$

Define:

$$(T_{ij,t}^s)^{-\theta^s} \equiv (\tau_{ij,t}^s)^{-\theta^s} (b_{ij,t}^s)^{1-\frac{\theta^s\sigma^s}{\sigma^s-1}} (f_{ij,t}^s)^{1-\frac{\theta^s}{\sigma^s-1}}. \tag{20}$$

Use the definition of $(T_{ij,t}^s)^{-\theta^s}$ from (20) to substitute in equations (18), (19), and (16). Then, rearrange terms in equations (18), (19), and (16) to obtain the following system:

$$X_{ij,t}^{sr} = \left(\frac{T_{ij,t}^s}{\Pi_{i,t}^s \tilde{P}_{j,t}^r}\right)^{-\theta^s} \frac{E_{j,t}^r Y_{i,t}^s}{Y_t^s}, \tag{21}$$

$$(\Pi_{i,t}^s)^{-\theta^s} = \sum_j \sum_r \left(\frac{T_{ij,t}^s}{\tilde{P}_{j,t}^r}\right)^{-\theta^s} \frac{E_{j,t}^r}{Y_t^s}, \tag{22}$$

$$(\tilde{P}_{j,t}^r)^{-\theta^s} = \sum_i \sum_s \left(\frac{T_{ij,t}^s}{\Pi_{i,t}^s}\right)^{-\theta^s} \frac{Y_{i,t}^s}{Y_t^s}, \tag{23}$$

System (21)-(23) looks familiar because it corresponds very closely to the one-sector structural gravity systems of Eaton and Kortum (2002) and Anderson and van Wincoop (2003). The difference is that system (21)-(23) is obtained with sectors and intersectoral trade, i.e., taking into account the full input-output structure within and between economies allowing for trade between sectors within a country as well as between different sectors across countries. Without sectors and intersectional trade, system (21)-(23) will be exactly identical to the demand-side system of Anderson and van Wincoop (2003), which, as is well established now can be re-expressed on the supply side as in Eaton and Kortum (2002). The main novelty in system (21)-(23) in relation to Eaton and Kortum (2002) and Anderson and van Wincoop (2003), which is also the main focus of this report, is the definition of bilateral trade costs, which now include the standard iceberg component plus tariffs plus fixed costs. As motivated earlier, expressing the generic trade model that we developed in the form of the well-known and now standard gravity systems is beneficial because it will enable us to discuss the decomposition of trade costs, which is the goal of the next section, as well as the aggregation of trade costs, which we target after that.

2.2 Trade Cost Decomposition

Following Larch and Yotov (2016) and Yotov et al. (2016), we use the generic structural gravity system (21)-(23) in order to decompose the influence of trade costs on bilateral trade in two steps. First, in Section 2.2.1, we distinguish between the influence of trade costs vs. size as the key determinant of trade flows and we isolate and define *total trade costs.* Then, in Section 2.2.2, we decompose total trade costs into their partial vs. general equilibrium components.

2.2.1 Total Trade Costs vs. Size

Consider a simplified version of the structural gravity equation (21), where we have simplified notation by focusing on a single sector in a cross section:[7]

$$X_{ij} \;=\; \left(\frac{T_{ij}}{\Pi_i \tilde{P}_j}\right)^{-\theta} \frac{E_j Y_i}{Y}, \tag{24}$$

As discussed in Larch and Yotov (2016), equation (24) can be decomposed into two terms: a size term, E_jY_i/Y, and a trade cost term, $(T_{ij}/(\Pi_i P_j))^{-\theta}$. The intuitive interpretation of the size term, E_jY_i/Y, is the hypothetical level of frictionless trade between partners i and j if there were no trade costs. This can be shown by eliminating all bilateral trade frictions, i.e., by setting $T_{ij} = 1$, and then re-deriving the structural gravity system (21)-(23), in which case the bilateral, frictionless trade between partners i and j would be $E_j^* Y_i^* / Y^*$, where the $*$ reflects the fact that the size variables would also change in response to the change in bilateral trade costs. Intuitively, a frictionless world implies that consumers will face the same price for a given variety regardless of their physical location and that their expenditure share on goods from a particular country will be equal to the share of production in the source country in the global economy, i.e. $X_{ij}^*/E_j^* = Y_i^*/Y^*$.

The prominent presence of the size term E_jY_i/Y in the structural gravity equation is a reflection of the intuitive relationships that large producers, as captured by Y_i, will export more to all destinations; large markets, as captured by E_j, will import more from all sources; and that trade flows between i and j will be larger the more similar in size the trading partners are. Anderson (2011) offers an insightful discussion and formal proofs of these and other, less obvious, properties based on the relationship between trade flows and country size in a frictionless world.

The second term in the gravity equation (24) is $(T_{ij}/(\Pi_i P_j))^{-\theta}$ and, as noted earlier, it

[7] All analysis in the decomposition sections and in the aggregation sections are readily extendable to across sectors and across time.

disappears in the absence of bilateral trade frictions. Thus, the natural interpretation of this term is as capturing the total effects of trade costs that drive a wedge between realized and frictionless trade. Agnosteva, Anderson and Yotov (2014) label the estimated version of this term *Constructed Trade Bias (CTB)* and define it as the ratio between realized trade and hypothetical frictionless trade. For consistency and for expositional purposes, we use the CTB index to define *Total Predicted Trade Costs (TPTC)*:

$$TPTC \equiv \left(\frac{\hat{T}_{ij}}{\hat{\Pi}_i \widehat{\hat{P}}_j}\right)^{-\theta}, \tag{25}$$

where $\hat{T}_{ij}$ is the estimate of bilateral trade frictions based on (20) and $\hat{\Pi}_i$ and $\widehat{\hat{P}}_j$ are constructed from system (22)-(23) for given data on output and expenditure along with the predicted measure of bilateral trade costs $\hat{T}_{ij}$. Agnosteva, Anderson and Yotov (2014) offer a detailed discussion of some attractive properties of $TPTC$, some of which are relevant for the current purposes. First, by construction, and as demonstrated above, $TPTC$ measures the *total bilateral trade costs* between partners i and j. Below, we discuss in detail the different components of $TPTC$. Second, $TPTC$ can be compared meaningfully not only across countries but also over time and across sectors as well. Third, $TPTC$ can be decomposed into several structural trade cost terms. We capitalize on this property in the next section. Fourth, $TPTC$ can be extended and consistently aggregated to a family of trade cost indexes some of which we discuss below. Finally, by construction (because it relies on estimates of the partial bilateral trade costs), $TPTC$ is a conditional expectation index and, as such, it is free of the random errors in mis-measured bilateral trade flow data. Estimating partial bilateral trade costs (i.e., ones that are net of general-equilibrium responses) will take central stage in this report and below we rely on the latest developments in the empirical gravity literature to obtain a comprehensive measure of the partial bilateral trade costs, , e.g., with the methods of Egger and Nigai (2016), and to decompose them into a series of observable and unobservable components. At the same time, and in contrast to the predicted $TPTC$

index, structural gravity theory allows for the construction of total trade costs directly from the data. To see this, rearrange terms in equation (24) to define:

$$TCTC_{ij} \equiv \left(\frac{T_{ij}}{\Pi_i \tilde{P}_j}\right)^{-\theta} = \frac{X_{ij}}{\frac{E_j Y_i}{Y}}, \tag{26}$$

where $TCTC$ denotes *Total **Calibrated** Trade Costs*. Two potential advantages of $TCTC$ in comparison to its predicted counterpart ($TPTC$) include: (i) $TCTC$ can be constructed directly from the data without the need to estimate parameters; and (ii) by construction, $TCTC$ matches the trade and production data perfectly. Furthermore, similar to its predicted counterpart, $TCTC$ (i) measures total trade costs; (ii) it can be compared consistently across countries, sectors and time; and (iii) it can be aggregated across various dimensions. We capitalize on some of these properties in Section 2.3 and in the empirical analysis below. The two main disadvantages of $TCTC$ are that: it is subject to measurement error critiques; and it is a composite of direct and indirect (GE) trade cost effects on trade. A decomposition of $TCTC$ is crucial for the current analysis. Therefore, in the following sections we focus our attention on $TPTC$, which allows for a meaning full decomposition of the total bilateral trade costs into their partial and general equilibrium components. A disadvantage of TCTC is though that it is not a policy variable in the sense that it depends on exogenous factors and parameters but also on endogenous variables such as prices and incomes.

2.2.2 Total vs. Partial vs. General Equilibrium Trade Costs

Trade theory and trade policy are done in a general equilibrium setting, where actions by single economies or by small groups of countries may have a significant impact and ripple effects through the whole world economy. This section builds and relies on the guidance of structural gravity theory to decompose and describe the links between partial vs. general equilibrium vs. total trade costs. To do so, consider the total trade cost term, which we defined in the previous section for a generic sector and year:

$$TPTC_{ij} \equiv \left(\frac{\hat{T}_{ij}}{\hat{\Pi}_i \hat{\tilde{P}}_j}\right)^{-\theta}. \tag{27}$$

$TPTC$ consists of three components.

$$\ln(TPTC_{ij}) = \ln \hat{T}_{ij}^{-\theta} + \ln \widehat{\Pi}_j^{\theta} + \ln \widehat{\tilde{P}}_j^{\theta}. \tag{28}$$

The first term on the right-hand side of equation (28) is the logarithm of the predicted bilateral trade cost term, $\hat{T}_{ij}^{-\theta}$. This term denotes the partial equilibrium bilateral trade costs between partners i and j. Based on the specification of bilateral trade costs from the structural gravity system, but using notation for a generic sector and year, define *Partial Equilibrium Trade Costs (PETC)*:

$$PETC_{ij} \equiv \hat{T}_{ij}^{-\theta} = (\hat{\tau}_{ij})^{-\hat{\theta}} (\hat{b}_{ij})^{1-\frac{\hat{\theta}\hat{\sigma}}{\hat{\sigma}-1}} (\hat{f}_{ij})^{1-\frac{\hat{\theta}}{\hat{\sigma}-1}}. \tag{29}$$

Proper measurement of $PETC$ is crucial for an analysis of the partial equilibrium as well as of the general equilibrium effects of trade policy. Modeling the partial equilibrium trade cost frictions, $PETC$, obtaining sound econometric estimates of these trade cost frictions, and decomposing them into their components, as captured in equation (29) is a central goal of this study. Accordingly, in the sections below, we devote significant attention to the construction of $PETC$.

In combination, the second and third terms on the right-hand side of equation (28) comprise the *General Equilibrium Trade Costs (GETC)* component of the total bilateral trade cost bill:

$$\ln(GETC_{ij}) \equiv \ln \widehat{\Pi}_j^{\theta} + \ln \widehat{\tilde{P}}_j^{\theta}. \tag{30}$$

The two terms on the right-hand side of (30) are the famous multilateral resistance terms (MRTs) of Anderson and van Wincoop (2003). Yotov et al. (2016) identify six main (and interrelated) properties of the MR terms. First, the MRTs bear the intuitive interpretation that, all else equal, two countries will trade more with each other the more remote they are from the rest of the world. Second, the MRTs are theory consistent aggregates of all possible bilateral trade costs to the country level. This property is readily visible from the definition of the MRTs in the system (22)-(23). Third, and also evident from system (22)-(23), the MRTs are general equilibrium trade cost terms, which capture the fact that a change in the partial equilibrium bilateral trade costs between any two partners will further affect trade between these partners as well as trade between all other countries in the world. Fourth, as emphasized by Anderson and Yotov (2010), the MRTs decompose the incidence of trade costs on consumers and producers in each country. Equation (22) shows that outward multilateral resistance is a weighted-average aggregate of all bilateral trade costs for the producers of goods in each country. It is as if each country i shipped its product to a single world market facing supply side incidence of trade costs Π_i. Similarly, Equation (23) defines the inward multilateral resistance as a weighted average of all bilateral trade costs that fall on the consumers in a region. It is as if each country j bought its goods from a single world market facing demand side incidence of P_j. Such a decomposition of trade costs should be important for policy analysis. Finally, the MRTs are straightforward to construct. Traditionally, the MRTs have been recovered by solving the non-linear system (22)-(23) with data on output, expenditure, and bilateral trade costs. However, more recently, it has been demonstrated (Arvis and Shepherd, 2013; Fally, 2015) that the general equilibrium MR indexes can actually be recovered directly from the estimates of the structural gravity fixed country(-sector-time) effects that are obtained from PPML gravity regressions. We capitalize on this property to recover the GE trade cost indexes that we present below.

Following the presentation and analysis in this section, our goal in the empirical analysis will be to measure total trade costs and to decompose them into their partial vs. general equilibrium trade cost components:

$$\ln(TPTC_{ij}) = \ln(PETC_{ij}) + \ln(GETC_{ij}). \tag{31}$$

We will devote particular attention to the measurement of $PETC$. Specifically, first we will obtain a comprehensive measure of the partial bilateral trade costs with the methods suggested by Egger and Nigai (2015) and Anderson, Larch and Yotov (2015), which combine the most appealing features of the "estimation" and of the "calibration" approaches to deliver partial bilateral trade costs that coincide with the corresponding calibrated vector, while at the same time allow fora decomposition of the partial bilateral trade costs into their key components. Then, we will employ this $PETC$ measure to obtain total trade costs. Note that the total predicted trade costs $TPTC$ that are obtained with partial bilateral costs based on the methods of Egger and Nigai (2015) and Anderson, Larch and Yotov (2015) will be identical to the total calibrated trade costs $TCTC$ that are obtained directly from the data. The difference is that the estimated partial bilateral trade costs of Egger and Nigai (2015) and Anderson, Larch and Yotov (2015) will enable us (i) to also construct general equilibrium trade costs $GETC$, as well as (ii) to decompose the $PETC$s into their components. Before we estimate the various trade cost indexes, we discuss the aggregation of trade costs.

2.3 Trade Cost Aggregation

Trade cost aggregation is necessary and important for policy analysis. This section follows the methods of Anderson and Neary (2005) and Agnosteva, Anderson and Yotov (2014) and capitalizes on the generic structural gravity framework that we developed in Section 2.1 in order to present theory-consistent methods for trade cost aggregation across various dimensions, e.g., across regions and across sectors. We will rely on these methods in the empirical analysis below. The analysis in this section focuses on aggregation over importing regions. However, similar principles and procedures apply to consistent aggregates over the other three dimensions of our analysis including exporting regions, exporting sectors, importing sectors, and combinations of those, e.g., across subgroups of importers and subgroup of importing sectors. We start with a discussion of aggregation methods for total trade costs. Then we consider the aggregation of partial trade costs.

2.3.1 Aggregating Total Trade Costs

There are several existing general equilibrium total trade cost indexes in the literature, which are all variations of $TPTC$ that are based on the structural gravity model. For example, Anderson and Yotov (2010) introduce *Constructed Home Bias (CHB)* as the ratio of predicted to hypothetical frictionless internal trade within a given country i:

$$CHB_i \equiv \frac{\hat{X}_{ii}}{Y_i E_i / Y} = \left(\frac{\hat{T}_{ii}}{\hat{\Pi}_i \hat{P}_i} \right)^{-\theta}. \tag{32}$$

Intuitively, CHB measures how far the economy is away from a frictionless trade equilibrium where $\hat{X}_{ii} = Y_i E_i / Y$. Anderson, Milot and Yotov (2014) complement the CHB index of Anderson and Yotov (2010) with the *Constructed Foreign Bias (CFB)*, defined as the ratio of the predicted volume of international export trade relative to the hypothetical frictionless volume of trade, and the *Constructed Domestic Bias (CDB)*, as the ratio of fitted to frictionless intra-national trade, excluding trade within sub-regions in a country. More recently, Agnosteva, Anderson and Yotov (2014) propose the CTB index, which we discussed earlier, and offer aggregation procedures for CTB.

We follow the methods of Agnosteva, Anderson and Yotov (2014) to aggregate total trade costs. Consider the aggregate trade volume from origin i to some subset of foreign destinations $R(i) = \{j \in R, j \neq i\}$, where we use R to denote sets of countries (the composite of which we refer to as a region):

$$\sum_{j \in R(i)} X_{ij} = \sum_{j \in R(i)} \frac{Y_i E_j}{Y} \left(\frac{T_{ij}}{\Pi_i P_j} \right)^{-\theta}. \tag{33}$$

By construction, region $R(i)$ excludes internal trade, and can also exclude any other bilateral trade depending on what is defined to be contained in R. For example, R can be defined as the countries from the European Union. The total predicted trade costs faced by the exporters in country i for shipments to region $R(i)$ are given by the ratio of the theoretical aggregate volume given above to the frictionless benchmark aggregate export volume $Y_i E_{R(i)}/Y$, where $E_{R(i)} \equiv \sum_{j \in R(i)} E_j$:

$$TPTC_{R(i)} = \sum_{j \in R(i)} \frac{E_j}{E_{R(i)}} TPTC_{ij}. \tag{34}$$

Intuitively, the total trade cost from exporter i to region $R(i)$ is the weighted average of the total bilateral trade costs between i and each of the countries in region j, with expenditures used as weights. In the import case, the expenditure share weights are replaced by sales share weights:

$$TPTC_{R(j)} = \sum_{i \in R(j)} \frac{Y_i}{Y_{R(j)}} TPTC_{ij}. \tag{35}$$

Similarly, sectoral expenditure shares and sectoral production shares can be used for consistent aggregation at the sectoral level on the exporter side and on the importer side, respectively.

2.3.2 Aggregating Partial Trade Costs

This section offers procedures and discussion for aggregating partial bilateral trade costs T_{ij} from i to destinations j in region $j \in R(i), j \neq i$. The procedures that we present follow the methods of Anderson and Neary (2005) and Yotov et al. (2016). For practical purposes, it is convenient (and approximately accurate for small sets) to ignore the effect of changes in $T_{ij}, j \in R(i)$, on the structural multilateral resistance terms Π_i, P_j. Then, for each exporter

i, the uniform bilateral trade cost index $B_{R(i)}$ can be implicitly defined as:

$$\sum_{j \in R(i)} X_{ij} = \sum_{j \in R(i)} \frac{Y_i E_j}{Y} \left(\frac{T_{ij}}{\Pi_i P_j} \right)^{-\theta} = \sum_{j \in R(i)} \frac{Y_i E_j}{Y} \left(\frac{B_{R(i)}}{\Pi_i P_j} \right)^{-\theta}. \tag{36}$$

Divide the middle and right-most terms of equation (36) by $(Y_i/\Pi_i^{-\theta} Y)$ and solve for $B_{R(i)}$:

$$B_{R(i)} = \left[\sum_{j \in R(i)} \frac{E_j P_j^{\theta}}{\sum_{k \in R(i)} E_k P_k^{\theta}} T_{ij}^{-\theta} \right]^{-1/\theta}. \tag{37}$$

Equation (37) revels that the aggregate of the partial bilateral trade cost index is a CES aggregator of the T_{ij}s, with weights $E_j P_j^{\theta} / (\sum_{k \in R(i)} E_k P_k^{\theta})$. Note that the economic interpretation of the weights is that they reflect "market potential" indexes of Redding and Venables (2004). Furthermore, as noted in Yotov et al. (2016), the weights can be constructed directly from the estimates of the importer fixed effects in a structural gravity regression. Let χ_j denote the estimates of the importer fixed effects (in levels) in structural gravity. Then, equation (37) becomes:

$$B_{R(i)} = \left[\sum_{j \in R(i)} \frac{\chi_j}{\sum_{k \in R(i)} \chi_k} T_{ij}^{-\theta} \right]^{-1/\theta}. \tag{38}$$

Similarly, partial equilibrium trade costs can be aggregated on the importer side as:

$$B_{R(i)} = \left[\sum_{i \in R(j)} \frac{\pi_i}{\sum_{k \in R(j)} \pi_k} T_{ij}^{-\theta} \right]^{-1/\theta}, \tag{39}$$

where, the aggregating weights are now the estimates of the exporter fixed effects π_i (in levels) from a structural gravity estimation. We will capitalize on the relationships from equations (38) and (39) in the empirical analysis. Similar procedure can be applied to aggregate any individual components (e.g., fixed or variable costs) of the partial bilateral trade costs $T_{ij}^{-\theta}$. Moreover, the proposed methods can be extended to accommodate aggregation across importing or exporting sectors too.

3 Quantifying Partial Equilibrium Trade Costs (PETC)

As demonstrated in the previous section, proper measurement of the direct bilateral trade costs is at the heart of any trade cost and trade policy analysis. Accordingly, the objective of this section is to develop and present methods for identification and decomposition of partial bilateral trade costs. In order to achieve this goal we start with a brief presentation of the leading methods to measure bilateral trade costs, including estimation vs. calibration vs. calculation, and we discuss their advantages and disadvantages. Based on this discussion, and given that one of the main objectives of this project is to decompose trade costs into their key components, we will develop and rely mostly on parametric techniques. However, we propose and employ a hybrid procedure to construct bilateral trade costs, which combines the most appealing features of the "estimation" and of the "calibration" approaches. The approach first estimates total barriers to trade and trade elasticities from a properly specified empirical gravity equation based on the generic structural trade model that we developed in the previous section. Then trade costs are decomposed into various components. As a result, our approach will deliver trade costs, which, subject to data availability, allow for a decomposition of their key components and enables to recover key response parameters, while at the same time fitting the producer-to-consumer sales data perfectly by construction.

3.1 Estimation vs. Calibration vs. Calculation

In this section we present and compare the three leading approaches to obtain measures of bilateral costs: i) parametrized trade-cost estimation, ii) calibration of trade costs, iii) calculation of trade costs using ratio-type methods. The main distinction between the parametrized trade cost estimation and the calibration and calculation approaches is that the former parametrize trade costs with some observable and possible unobservable country-and/or pair-specific or country-sector- and/or pair-sector-specific components, while the calibration approach backs out trade costs by "inverting" positive market-to-market sales for them without residual based on some structural model assumption, and the calculation approach uses ratios of different market-to-market sales. Note that the calculation approach uses data and theory to back out partial trade costs without perfectly fitting unilateral (export or import) data but only symmetrified (log export plus log import) data. As it is inspired by theory akin to the calibration approach and does not generate residuals on symmetrified bilateral trade data, the calculation approach may be viewed as a variant of calibration.[8]

Most recently, the academic literature has seen a surge in the use of calibration and calculation techniques to measure bilateral trade costs. Such methods include a series of ratio-type calculation methods for bilateral producer-to-consumer trade costs, which recover theory-consistent partial bilateral trade costs directly from the data by eliminating the country-specific structural terms (Head and Ries, 2001; Romalis, 2007; Head, Mayer and Ries, 2010; Novy, 2013; Simonovska and Waugh, 2014; Caliendo and Parro, 2015). In addition, scholars often rely on the "exact hat" algebra specification of the structural gravity system in changes using producer-to-consumer-market sales shares following Dekle, Eaton and Kortum (2007, 2008), which can be viewed as an extension of the calibration approach to perform counterfactual quantification analysis.

Several attractive features (at least from an academic perspective) have made the calibration and calculation methods popular among scholars. The main advantage of the calibration approach towards partial trade costs is that it fits positive market-to-market sales data perfectly. Further, it is easy to apply. Similarly, the calculation of partial trade costs based on ratios of positive market-to-market sales is easy to implement with a good (even though

[8]Ratio and calculation methods for trade costs are used by Head and Ries (2001) or Caliendo and Parro (2015). However, as Egger and Staub (2016) note, researchers should be cautious about parameter inference made from models that use trade flow ratios to estimate parameters. The standard errors obtained from regression cannot be used at face value but need to be adjusted ex post.

not perfect) fit to the data. However, the calibration and calculation methods may present a number of challenges for policy analysis.

First, they are unable to identify the effects of specific liberalization and market access policies. For example, the approach of calibrating or calculating partial trade costs can estimate the effects of a ten percent decrease in *all* partial trade costs, but it cannot determine what kind of policy can lead to such a decrease, nor can it distinguish between variable and fixed trade costs. Thus, while elegant from a theoretical perspective, the calibration and calculation approaches may not be very informative from a policy perspective. Second, since it lacks any residual by definition, the calibration approach cannot be used to test the model specification and underlying hypotheses (see for example Dawkins, Srinivasan and Whalley, 2001; Krugman, 2011), since it uses as many parameters as there are data points in order to completely close the gap between a model and the data. Clearly, potentially infinitely many models exist which can be calibrated fully to the data in such way, and a statistical distinction between them is not possible.

The main advantage of the parametrized partial trade-cost estimation approach is that it potentially can estimate the causal effects of any kind of policy. Another advantage is that the estimation approach automatically delivers a decomposition of the estimated bilateral barriers to trade and market access into their underlying components, in particular, variable vs. fixed and domestic vs. cross-border components. The main disadvantages of the estimation method are that it is more demanding in terms of implementation, it is prone to parameter bias upon model misspecifications, and it does not fit the underlying market-to-market sales data perfectly.

Based on this discussion, and given that one of the main objectives of this project is to decompose trade costs into their key components, we will develop and rely mostly on parametric techniques. However, to the extent possible, we will attempt to "reconcile" calibration versus parametrized estimation of variable market access costs by combining them and by decomposing total partial trade costs into observable versus "unexplained" or unobservable trade costs, thus trying to take advantage of the best features of all methods to measure partial trade costs. To that end, we propose and employ a hybrid procedure to construct bilateral partial trade costs suggested by Egger and Nigai (2015) and Anderson, Larch and Yotov (2015), which combines the most appealing features of the "estimation" and of the "calibration" approaches. The approach first estimates total barriers to trade and trade elasticities from a properly specified empirical gravity equation based on the generic structural trade model that we developed in the previous section. Then trade costs are decomposed into various components. Our approach will deliver trade costs, which, subject to data availability, allow for a decomposition of their key components and enables one to recover key response parameters, while at the same time fitting the producer-to-consumer sales data perfectly by construction.

3.2 Identifying Bilateral Trade Costs and Trade Elasticities

This section outlines a three-step hybrid approach to recover bilateral trade costs and trade elasticities. Step 1 delivers measures of the total bilateral trade cost frictions following the methods of Egger and Nigai (2015). Importantly, our total trade cost indexes are consistent across the estimation vs. calibration vs. calculation methods discussed in the previous section. Step 2 proposes methods to recover the key elasticity parameters. Finally, Step 3 develops procedures to decompose bilateral trade frictions. The methods we propose in this section are parametric and, therefore, we here also discuss the main challenges with structural gravity estimations as well as the best practices to address them.

3.2.1 Step 1: Recovering Total Bilateral Frictions

Note that the equation for expenditure shares in (9) is log-linear in the exporter-sector-time ($e^s_{i,t}$), importer-sector-time ($m^r_{j,t}$), and pair-sector-time ($d^s_{ij,t}$) components and can be rewritten as:[9]

$$\ln\left(\lambda_{ij,t}^{sr}\right) = e_{i,t}^{s} + d_{ij,t}^{s} + m_{j,t}^{r}. \tag{40}$$

Once normalizing this expression by $\lambda_{jj,t}^{sr}$ and after setting $d_{jj,t}^{s} = 1$ for all i, s, t, we obtain[10]

$$\ln\left(\frac{\lambda_{ij,t}^{sr}}{\lambda_{jj,t}^{sr}}\right) = e_{i,t}^{s} + d_{ij,t}^{s} - e_{j,t}^{s}. \tag{41}$$

We follow Eaton and Kortum (2002) in estimating a stochastic version of (41) with a set of suitable constraints to obtain:

$$\ln\left(\frac{\lambda_{ij,t}^{sr}}{\lambda_{jj,t}^{sr}}\right) = e_{i,t}^{s} + d_{ij,t}^{s} - e_{j,t}^{s} + \epsilon_{ij,t}^{sr} \text{ such that } e_{i,t}^{s} = e_{j,t}^{s} \;\; \forall i = j \text{ and } s \neq r, \tag{42}$$

where $\epsilon_{ij,t}^{sr}$ is an idiosyncratic stochastic term.

For each sector $s \in \mathfrak{S}$ and time period $t \in \mathfrak{T}$ we have $(S-1)J(J-1)$ observations and estimate $J(J-1)$ bilateral components $d_{ij,t}^{s}$ and J exporter-specific components $e_{i,t}^{s}$ using fixed effects. In this first step, the estimation may be and is performed separately for each sector and year.[11] It is also worth mentioning that the residual term $\epsilon_{ij,t}^{sr}$ may potentially be attributed to $d_{ij,t}^{s}$. While, we report most of the results for $d_{ij,t}^{s}$ that does not include the residuals, we have also calculated them for $(d_{ij,t}^{s} + \epsilon_{ij,t}^{sr})$ as an alternative measure of partial trade costs in logs.

[9] Note that $d_{ij,t}^{s} = (\tau_{ij,t}^{s})^{-\theta^{s}} \left(b_{ij,t}^{s}\right)^{1-\frac{\theta^{s}\sigma^{s}}{\sigma^{s}-1}} (f_{ij,t}^{s})^{1-\frac{\theta^{s}}{\sigma^{s}-1}}$. In equation (29) we defined $PETC_{ij}$ as $PETC_{ij} \equiv \hat{T}_{ij}^{-\theta} = (\hat{\tau}_{ij})^{-\hat{\theta}}(\hat{b}_{ij})^{1-\frac{\hat{\theta}\hat{\sigma}}{\hat{\sigma}-1}}(\hat{f}_{ij})^{1-\frac{\hat{\theta}}{\hat{\sigma}-1}}$. We could define $PETC$ similarly at the country level and over time, i.e., $PETC_{ij,t}^{s}$, which shows that $PETC_{ij,t}^{s} = (\hat{T}_{ij,t}^{s})^{-\theta^{s}} = d_{ij,t}^{s}$.

[10] Some recent work makes an effort to quantify domestic trade costs. However, most of that work is cast in a regional economic context, where countries are not points but are composed of a mass of regions (see, e.g. Allen and Arkolakis, 2014; Desmet, Nagy and Rossi-Hansberg, 2018). However, in country-level quantitative trade models, the average level of productivity (or endowments) and average shipping costs are collinear with each other and with country-(sector-time)fixed effects, it is customary practice to make the normalization that $d_{jj,t}^{s} = 1$ for all i, s, t. This implies that any producer-country-sector-time residual of log domestic trade, after properly deducting factor costs, is interpreted as a scaled productivity (or endowment) measure, and all bilateral log trade costs are measured as deviations from domestic trade costs.

[11] Alternatively, we have estimated equation (42) across all years for each sector. The results are available upon request.

3.2.2 Step 2: Estimating θ^s and σ^s

Before proceeding to the decomposition of total bilateral trade frictions, we estimate the structural parameters θ^s and σ^s for each sector. The former reflects the shape parameter of the underlying Pareto distribution of firm productivity in sector s, and the latter governs the elasticity of substitution between different goods in a given sector. Clearly, estimating of some compound measure of θ^s and σ^s on either variable trade costs or factor returns would mean to estimate what is commonly referred to as the *trade elasticity* (see Feenstra, 1994; Broda and Weinstein, 2006; Caliendo and Parro, 2015, for earlier examples). However, disentangling θ^s and σ^s is more in the spirit of quantitative work based on firm-level data as in Corcos et al. (2012), where we only have macro data at hand, here. Readers should not compare the parameters in, say, Broda and Weinstein (2006) or Caliendo and Parro (2015) to the ones here, as the fundamental model structures are different.

We first estimate θ^s. Recall that we have $J \times S \times T$ exporter-sector-time-specific parameters, $\widehat{e}^s_{i,t}$ from Step 1. This composite is linear in the log unit cost measure in sector s and country i in time t, $c^s_{i,t}$, such that we can run the following regression to estimate $\xi^s = 1 - \frac{\theta^s \sigma^s}{\sigma^s - 1}$ from:

$$\widehat{e}^s_{i,t} = \xi^s c^s_{i,t} + \mu_t + res^s_{i,t}, \tag{43}$$

where μ_t is a t-specific fixed effect and $res^s_{i,t}$ is a residual term that includes other $\{its\}$-specific variables not captured by $c^s_{i,t}$, whose factor-cost-components we assume to be observable. Naturally, $c^s_{i,t}$ may be an imperfect measure of the log of true unit costs, and to avoid the problems associated with such measurement errors we instrument for $c^s_{i,t}$ in estimating (43) using the following instrument:

$$H^s_{i,t} = (share^s_{i,1995} L_{i,t}) \left(\frac{1}{J} \sum_j d^s_{ij,t} \right) \text{ for all } t > 1995, \tag{44}$$

where $d^s_{ij,t}$ reflects total bilateral frictions between the two countries and sector and

$share^s_{i,1995} L_{i,t}$ is employment in the exporter country and sector in a given period. In other words, we instrument the unit cost using the employment-scaled average trade frictions for a given producer country, sector, and year. Note that this instrument is relevant for unit costs according to the standard trade balance condition.[12]

Next, we estimate the sector-specific elasticity parameter σ^s. For that, recall that we can recover the importer-sector-time-specific parameter, $m^r_{j,t}$, from the structural equation (10) for trade flows:

$$\widehat{m}^s_{i,t} = \ln\left(X^{ss}_{ii,t}\right) - \widehat{e}^s_{i,t}. \tag{45}$$

The estimate $\widehat{m}^s_{i,t}$ can be used to structurally estimate $\gamma^s = \frac{\theta^s}{\sigma^s - 1}$ from

$$\widehat{m}^s_{i,t} = \gamma^s y^s_{i,t} + \nu^s c^s_{i,t} + \mu_t + res^s_{i,t}, \tag{46}$$

where $y^s_{i,t} = \ln Y^s_{i,t}$ and expenditures $Y^s_{i,t}$ are observable and measured from bilateral sales data from WIOD. However, also $y^s_{i,t}$ in equation (46) may be endogenous. We use the instrument specified in equation (44) to control for possible endogeneity and omitted variables.

Using the estimates of the composite parameters ξ^s and γ^s, we can recover the structural model parameters σ^s and θ^s as:

$$\hat{\sigma}^s = \frac{1 - \hat{\xi}^s}{\hat{\gamma}^s} \quad \text{and} \quad \hat{\theta}^s = \frac{(1 - \hat{\xi}^s)(\hat{\sigma}^s - 1)}{\hat{\sigma}^s}. \tag{47}$$

With estimates of θ^s and σ^s at hand, we can proceed to decomposing total partial trade frictions in logs, $d^s_{ij,t}$, into their variable and fixed components.

Note that the proposed identification of the parameters θ^s and σ^s is similar in spirit to the ones in Chaney (2008), Arkolakis, Costinot and RodrÃguez-Clare (2012), and Corcos et al.

[12] Note that this instrument is valid irrespective of whether trade is balanced as in Eaton and Kortum (2002) or not as in Dekle, Eaton and Kortum (2007). In either case, country-sector productivity and the mass of households and workers in an economy (and, with an immobility of factors between sectors, the ones active in a sector) are exogenous shifters to the wages earned in an economy.

(2012).

3.2.3 Step 3: Decomposing Total Bilateral Frictions

Our recovered bilateral variable from Step 1, $\widehat{d}^{s}_{ij,t}$, is a log-linear function of tariffs, variable trade costs, and fixed trade costs. According to the model, we can formulate total bilateral frictions as:

$$-\,d^{s}_{ij,t} = \theta^{s}\ln\left(\tau^{s}_{ij,t}\right) + \left(\frac{\theta^{s}\sigma^{s}}{\sigma^{s}-1} - 1\right)\ln\left(b^{s}_{ij,t}\right) + \left(\frac{\theta^{s}}{\sigma^{s}-1} - 1\right)\ln\left(f^{s}_{ij,t}\right). \tag{48}$$

In equation (48), bilateral ad-valorem tariffs, $b^{s}_{ij,t}$, can be measured, so that we can define a new variable

$$\kappa^{s}_{ij,t} = -d^{s}_{ij,t} - \left(\frac{\theta^{s}\sigma^{s}}{\sigma^{s}-1} - 1\right)\ln\left(b^{s}_{ij,t}\right) = \theta\ln\left(\tau^{s}_{ij,t}\right) + \left(\frac{\theta^{s}}{\sigma^{s}-1} - 1\right)\ln\left(f^{s}_{ij,t}\right). \tag{49}$$

We will use equation (49) to parametrize transport costs, $\tau^{s}_{ij,t}$, as a function of observables and parametrize fixed costs $f^{s}_{ij,t}$ as a function of another set of observables as well as of some unobservable measures.

4 Data: Description and Sources

This section presents our data and describes the data sources and potential caveats with the data too. In order to perform the main empirical analysis, we will use the World-Input-Output-Database (WIOD), which covers 41 countries and an aggregate rest-of-the-world region for the period from 1996 to 2011. Thus, by construction, the WIOD dataset covers the complete word economy. The sectoral coverage of WIOD includes 35 sectors, of which 16 sectors can be classified as manufacturing. Thus, the WIOD predetermines the dimensions of our analysis to 41 countries and 35 sectors over the period 1996-2011.

Several advantages of WIOD make it particularly appropriate for our analysis. First, the

WIOD data includes consistently constructed domestic sales (i.e., internal or domestic trade). Second, the WIOD data offers a comprehensive sectoral coverage, which adds to the total sales and production for each country in the database. This will enable us to aggregate our sectoral indexes in order to construct consistent trade costs at the country level. Third, the WIOD data can be combined with the Socio Economic Accounts database, which will enable us to construct unit costs that are needed for the structural analysis. In addition to the WIOD data of trade and production, we will use a series of other datasets, which will enable us to measure and decompose trade costs into various components. Additionally, we use World Bank's World Integrated Trade Solution Database (WITS), the WTO's I-TIP database, which offers data on a series of NTMs and stretches back to 1996, the OECD Structural Business Statistics, and the CEPII database, which includes data on a number of standard determinants of trade costs.

One disadvantage of the WIOD dataset is its relatively low coverage in terms of number of separate countries. There are only 41 countries that are included separately. WIOD includes a rest-of-the-world aggregate that covers many small countries, and the developers assure that, in combination with the countries that are explicitly included, the rest-of-the-world aggregate region delivers coverage of the complete world economy. However, due to is widely heterogeneous nature, any estimates of trade costs for the rest-of-the-world aggregate region should be interpreted with caution.

While our empirical analysis is limited in terms of data coverage, the methods that we develop and present in this report can be applied and extended to any set of countries for which consistent intra- and international trade flows are available. In addition, we note that: (i) since, as demonstrated in the theoretical section of our report, gravity theory is separable, our methods apply to any sectoral level of aggregation and they are able to accommodate any specific sectoral classification or addition of more sectors; and (ii) naturally, our methods can be extended to accommodate more years for which data are available, pre or post the sample that is used in the current investigation. In sum, the methods developed in this study can be easily applied to any updates or new data sets covering more countries, more sectors, and more years.

Finally, we note that one can make out-of-sample predictions beyond the data covered, which is equivalent to constructing missing data. This depends on which data are missing, intranational and/or international. See for a first attempt in this direction Anderson et al. (2015).

Next, we offer a detailed description of our data sources and coverage in Subsection 4.1 as well as a discussion of some key descriptive statistics in Subsection 4.2.

4.1 Data Sources and Coverage

In this section, we describe the data sources, coverage of countries, sectors, and years. The principal source of our data is the World Input Output Database (WIOD) which covers 41 countries listed in Table 1.

The data distinguishes between 35 sectors, of which 16 sectors can be classified as manufacturing. We enumerate these sectors and sort them such that the manufacturing sectors take on the lowest 16 numbers. We list the covered 16 manufacturing sectors in Table 2 and the covered 19 services sectors in Table 3. Overall, this classification of sectors corresponds to a two-digit classification in customary industry classification frameworks. Note that unless specified otherwise, manufacturing sectors include also agriculture.

We use balanced data from WIOD on the aforementioned countries and sectors in 16 individual years between 1996 and 2011.

Beyond the aforementioned data on trade (and expenditures) from WIOD, we employ ones on tariffs from the World Bank's World Integrated Trade Solution Database (WITS) and on bilateral gravity variables from the CEPII database. The tariff data are available at

Table 1: *Country Coverage*

j	Country	ISO-code	j	Country	ISO-code
1	Australia	AUS	22	Italy	ITA
2	Austria	AUT	23	Japan	JPN
3	Belgium	BEL	24	Korea	KOR
4	Bulgaria	BGR	25	Lithuania	LTU
5	Brazil	BRA	26	Luxembourg	LUX
6	Canada	CAN	27	Latvia	LVA
7	China	CHN	28	Mexico	MEX
8	Cyprus	CYP	29	Malta	MLT
9	Czech Republic	CZE	30	Netherlands	NLD
10	Germany	DEU	31	Poland	POL
11	Denmark	DNK	32	Portugal	PRT
12	Spain	ESP	33	Romania	ROU
13	Estonia	EST	34	Russia	RUS
14	Finland	FIN	35	Rest of the World	RoW
15	France	FRA	36	Slovakia	SVK
16	Great Britain	GBR	37	Slovenia	SVN
17	Greece	GRC	38	Sweden	SWE
18	Hungary	HUN	39	Turkey	TUR
19	Indonesia	IDN	40	Chinese Taipei	TPKM
20	India	IND	41	United States	USA
21	Ireland	IRL			

Table 2: *Manufacturing Sectors*

s	Sector
1	Agriculture, Hunting, Forestry and Fishing
2	Mining and Quarrying
3	Food, Beverages and Tobacco
4	Textiles and Textile Products
5	Leather, Leather Products and Footwear
6	Wood and Products of Wood and Cork
7	Pulp, Paper, Printing and Publishing
8	Coke, Refined Petroleum and Nuclear Fuel
9	Chemicals and Chemical Products
10	Rubber and Plastics
11	Other Non-Metallic Mineral
12	Basic Metals and Fabricated Metal
13	Machinery, Nec
14	Electrical and Optical Equipment
15	Transport Equipment
16	Manufacturing, Nec; Recycling

Table 3: *Service Sectors*

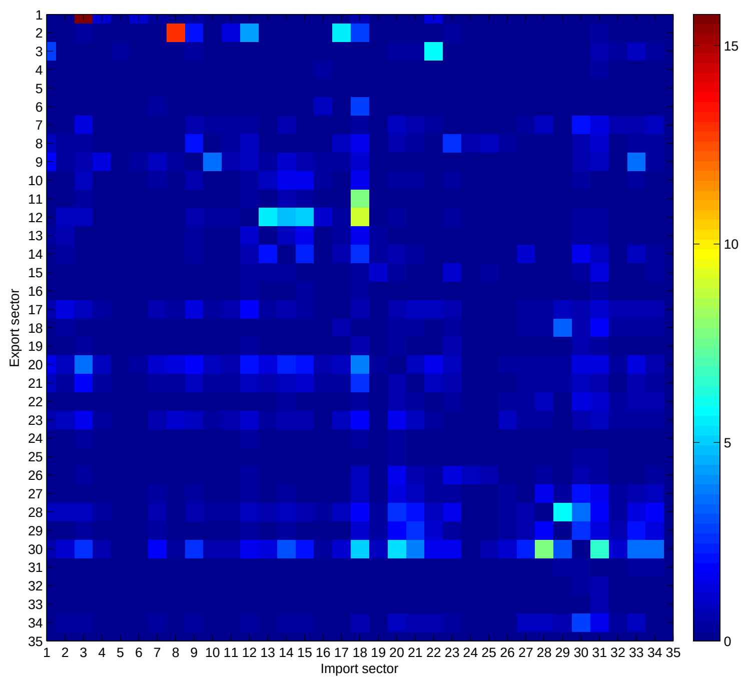
s	Sector
17	Electricity, Gas and Water Supply
18	Construction
19	Sale, Maintenance and Repair of Motor Vehicles and Fuel
20	Wholesale Trade and Commission Trade, Except of Motor Vehicles
21	Retail Trade, Except of Motor Vehicles; Repair of Household Goods
22	Hotels and Restaurants
23	Inland Transport
24	Water Transport
25	Air Transport
26	Other Supporting and Auxiliary Transport Activities and Agencies
27	Post and Telecommunications
28	Financial Intermediation
29	Real Estate Activities
30	Renting of M&Eq and Other Business Activities
31	Public Admin and Defence; Compulsory Social Security
32	Education
33	Health and Social Work
34	Other Community, Social and Personal Services
35	Private Households with Employed Persons

the 2-digit ISIC-3 level and were downloaded from the WITS. The effective transportation distance is from Egger and Loumeau (2018). We also use data on the firm size distribution from the OECD Structural Business Statistics.

Finally, we employ the WIOD Socio-Economic Accounts (SEA) (http://www.wiod.org/database/seas13), which are fully consistent with the World Input-Output Database (WIOD) that we use to construct our trade costs. We use the WIOD-SEA database in order to construct two alternative measures of skill intensity, namely (i) labor compensation of low, medium and high skilled works as a share of total labor compensation as well as (ii) hours worked by low, medium and high skilled workers as a share of total hours worked. These measures are used to decompose trade costs across skilled groups for each country in our sample.

4.2 Descriptive Statistics of Key Variables

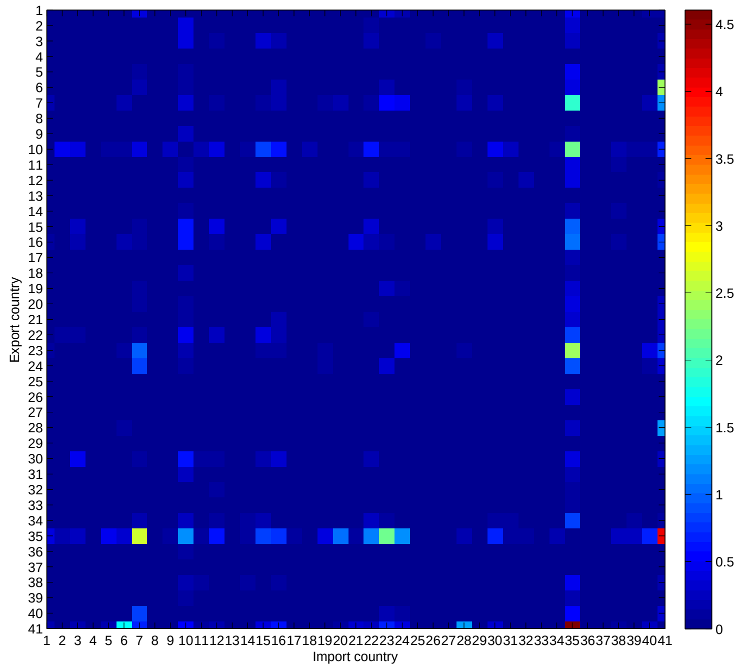
We begin to describe the data in WIOD through a visualization. In Figures 1 and 2, we use a grid representation each to portray aggregate sales in the average year between 1995 and 2011 in WIOD between sector pairs $\{sr\}$ and country pairs $\{ij\}$, respectively. As domestic sales are relatively dominant in size, we exclude them from Figure 2 and describe them separately below. The WIOD captures cross-sectoral flows within and between countries. Figures 1 and 2 show that there are a few sector-country links that are a lot stronger than all others are. Hence, focusing only on aggregates hides some details that are important when quantifying trade costs.



Notes: The data cover cross-sectoral flows within and between countries. The sector numbers are from Tables 2 and 3.

Fig. 1: *Aggregate Sales From Sector s to Sector r Across All Countries in 1996-2011*

The purpose of Figures 1 and 2 is to show that trade is relatively concentrated among specific sector pairs as well as country pairs. However, all sector-to-sector relations and all country-to-country relations in WIOD are "used", i.e., show some positive sales. In any case the volume of transaction values between sector and country pairs displays a high degree



Notes: The data cover cross-sectoral flows within and between countries. The country numbers are from Table 1.

Fig. 2: *Aggregate Cross-Border Sales (Exports) From Country i to Country j Across All Sectors in 1996-2011*

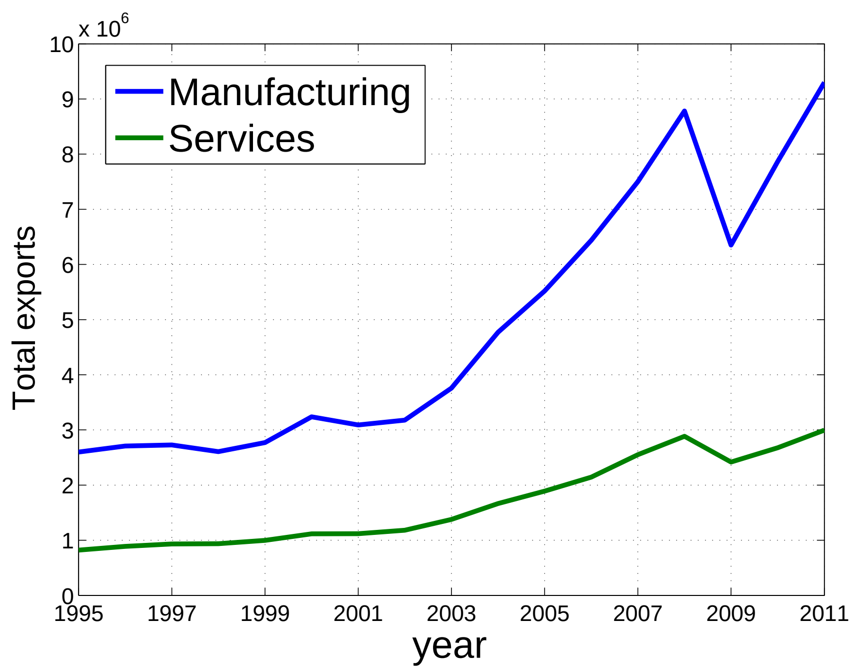


Fig. 3: *Aggregate Cross-Border Sales (Exports) Among All Countries and Sectors Across Years*

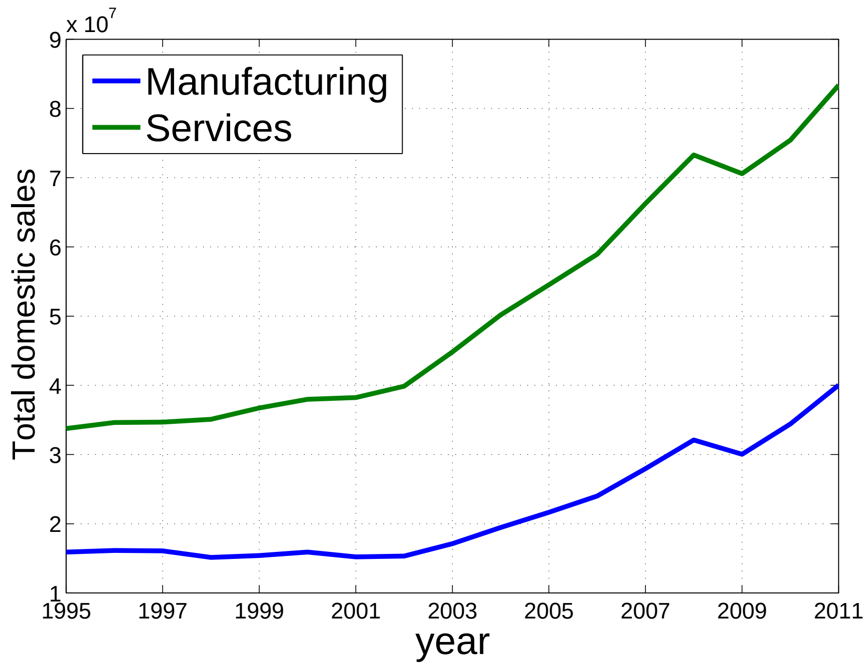


Fig. 4: *Aggregate Domestic Sales Among All Countries and Sectors Across Years*

of variance. While Figures 1 and 2 take a bilateral (sector-by-sector or country-by-country) perspective, we aggregate cross-border sales up over all countries and sectors and display their trend across the covered years for manufactures (sectors 1-16) and services (sectors 17-35) separately in Figure 3. That figure clearly suggests that the trade in manufactures dominates the one in services, but also the volatility of the cross-border sales of manufactures is higher than the ones of services on average. Figure 4 does the same as Figure 3 but for domestic rather than cross-border sales. Considering the bigger scale of domestic sales in comparison to export sales on the vertical axes of the two figures, it clearly indicates that services sales at large dominate the sales of manufactures. The former – namely the bigger level of cross-border sales of manufactures – in conjunction with the notion that the sales and value added of services are much bigger in the considered countries on average than the ones of manufactures points to the potentially greater importance of services trade costs than trade costs on manufactures (see Egger, Larch and Staub, 2012, for this argument).

5 Estimation Results

This section presents our main findings. The section begins with a presentation and a discussion of the key structural parameters in the model. Next, we obtain and discuss our measures of bilateral trade cost indexes, which are decomposed into the two key dimensions of interest, i.e., variable vs. fixed trade costs. Then, the bilateral trade costs are used to construct general equilibrium trade costs as well as a series of trade cost indexes across various horizontal and vertical dimensions.

5.1 Estimating $\{\xi^s, \gamma^s\}$ and $\{\sigma^s, \theta^s\}$

Using the procedure described in Subsection 3.2.2 on the aforementioned data, we obtain sector-level composite parameters ξ^s and γ^s which we summarize in Table 4.[13]

Table 4: *Estimated Composite Parameters*

s	ξ^s	s.e.	γ^s	s.e.	s	ξ^s	s.e.	γ^s	s.e.
1	-4.64	0.14	1.31	0.01	19	-3.22	0.13	1.62	0.02
2	-4.17	0.13	1.27	0.02	20	-4.25	0.12	1.39	0.01
3	-4.63	0.14	1.29	0.01	21	-2.77	0.14	1.48	0.01
4	-4.59	0.14	1.19	0.01	22	-4.17	0.13	1.53	0.02
5	-3.43	0.13	1.19	0.02	23	-4.71	0.14	1.38	0.01
6	-4.36	0.13	1.35	0.01	24	-4.23	0.13	1.31	0.03
7	-4.68	0.14	1.27	0.01	25	-3.62	0.11	1.41	0.02
8	-4.06	0.14	1.37	0.02	26	-4.77	0.14	1.38	0.01
9	-4.76	0.15	1.16	0.01	27	-4.79	0.15	1.36	0.01
10	-4.55	0.15	1.29	0.01	28	-4.44	0.13	1.30	0.01
11	-4.34	0.14	1.36	0.01	29	-3.71	0.13	1.40	0.01
12	-4.35	0.14	1.21	0.01	30	-4.16	0.12	1.28	0.01
13	-4.40	0.13	1.22	0.01	31	-4.54	0.16	1.47	0.02
14	-4.73	0.14	1.17	0.01	32	-4.33	0.13	1.58	0.02
15	-4.40	0.13	1.17	0.01	33	-4.15	0.12	1.45	0.02
16	-4.53	0.14	1.34	0.02	34	-4.79	0.14	1.35	0.01
17	-4.17	0.14	1.34	0.01	35	-3.18	0.2	4.96	1.25
18	-3.52	0.15	1.35	0.01					

[13]The parameters in Table 4 are indexed by (sector) s only. Hence, they are obtained from regressions which pool the data on countries and years for one sector each.

Clearly, as ξ^s and γ^s are composite parameters, a direct interpretation of their magnitude is not supported by economic theory. However, these parameters suggest the corresponding parameter estimates of σ^s and θ^s as summarized in Table 5, which can be interpreted.

Table 5: *Estimated Structural Parameters*

s	σ^s	θ^s	s	σ^s	θ^s
1	4.30	4.33	19	2.61	2.60
2	4.07	3.90	20	3.78	3.86
3	4.37	4.35	21	2.55	2.29
4	4.70	4.40	22	3.37	3.63
5	3.73	3.24	23	4.14	4.33
6	3.99	4.02	24	3.98	3.92
7	4.47	4.41	25	3.29	3.22
8	3.69	3.69	26	4.18	4.39
9	4.96	4.60	27	4.27	4.44
10	4.30	4.26	28	4.18	4.13
11	3.94	3.99	29	3.37	3.31
12	4.41	4.14	30	4.02	3.88
13	4.42	4.18	31	3.77	4.07
14	4.91	4.56	32	3.38	3.76
15	4.63	4.23	33	3.55	3.70
16	4.11	4.19	34	4.30	4.44
17	3.86	3.83	35	3.51	2.99
18	3.34	3.17			

Regarding σ^s, a higher parameter means more competition – through a more elastic reaction of demand to higher prices on output. The results suggest at large that σ^s tends to take on lower values for services than for manufactures, whereby we would conclude that services are more differentiated and face less competition, so that markups should be higher. This finding of Table 5 is interesting to see in conjunction with the pattern of there being a lower level of services trade (in spite of overall higher sales) in comparison to trade in manufactures. These two findings together suggest that services are less competitive and competition from abroad is lower than for manufactures.[14]

Notice that $\widehat{\sigma}^s > 0$ as is required, and $\widehat{\sigma}^s$ is largest – and, hence, competition is toughest – for Chemicals and Chemical Products ($\widehat{\sigma}^s \approx 4.96$), followed by Electrical and Optical Equipment ($\widehat{\sigma}^s \approx 4.92$), and Textiles and Textile Products ($\widehat{\sigma}^s \approx 4.70$). All of the mentioned sectors belong in manufacturing. At the other end, $\widehat{\sigma}^s$ is lowest – and, hence, competition is least tough – in Retail Trade – ($\widehat{\sigma}^s \approx 2.55$), followed by Sale, Maintenance and Repair of Motor Vehicles and Fuel ($\widehat{\sigma}^s \approx 2.60$). All of those are services sectors.[15] Comparing these results with the ones obtained by Broda and Weinstein (2006), who conclude that homogeneous goods have higher elasticities of substitution than goods that are classified as reference priced or differentiated according to Rauch (1999), we could argue for a similar pattern due to the higher degree of differentiability of services. This is also in line with findings by Egger, Larch and Staub (2012). We refer the reader to Costinot and RodrÃguez-Clare (2014) and Head and Mayer (2014) who offer a summary elasticity estimates and for discussion of the available methods to obtain estimates of the elasticity of substitution and trade elasticity parameters.

The parameter θ^s governs the shape of the distribution – and, hence, the variation – of firm productivity in a sector. In general, larger values of θ^s are associated with a smaller dispersion of productivity in a sector. For an equilibrium to exist, it must be the case that $\widehat{\theta}^s > \widehat{\sigma}^s - 1$ which we found throughout all sectors without having imposed this inequality constraint. The results suggest at large that θ^s tends to take on lower values for services than for manufactures, and, hence, the dispersion of productivity in services tends to exceed

[14] We refrain from reporting standard errors or confidence intervals of the parameters in Table 5. The reason is that these parameters are "derived" based on the estimates of the composite parameters in Table 4. One could obtain confidence intervals by assuming normality of the parameters in Table 4 and sampling from a normal distribution with the parameter means and standard errors in Table 4. However, since the parameters in Table 4 are obtained from a multi-step procedure as outlined in Section 3.2, and as numerous fixed effects are involved (which imply non-iid data), the procedure to obtain standard errors on the parameters in Table 5 is cumbersome and would involve a multi-block sampling (as an analogue to a multi-clustering approach based on an appropriate bootstrap).

[15] Note that the calculated σ^s for "Private Households with Employed Persons" did not obey sign restrictions. This is likely to be due to noisy measurement of this economic activity. Hence, we replace σ^s in that sector with an average across the service sectors in the sample.

the one in manufacturing. However, the pattern of the estimates $\widehat{\theta}^s$ between services and manufactures is slightly less clear-cut than this was the case with $\widehat{\sigma}^s$.

We find that $\widehat{\theta}^s$ is largest – and, hence, the productivity dispersion is lowest – for Chemicals and Chemical Products ($\widehat{\theta}^s \approx 4.60$), followed by Electrical and Optical Equipment ($\widehat{\theta}^s \approx 4.56$). At the other end, $\widehat{\theta}^s$ is lowest – and, hence, the productivity dispersion is biggest – for Retail Trade ($\widehat{\theta}^s \approx 2.29$), followed by Sale, Maintenance and Repair of Motor Vehicles and Fuel ($\widehat{\theta}^s \approx 2.60$). All of those are services sectors.

5.2 Estimating and Decomposing Trade and Market Access Costs $\{\tau^s_{ij,t}, f^s_{ij,t}\}$

In order to estimate and disentangle non-tariff trade costs from market-access costs, recall the structural equation for the composite of the two, namely $\kappa^s_{ij,t}$ in equation (49). Our strategy of disentangling $\tau^s_{ij,t}$ from $f^s_{ij,t}$ therein is to use observable variables and parameterizing the two components. Our main variable capturing variable costs beyond tariffs is the ad-valorem equivalent to transportation costs which is measured as the surface distance between two countries over the route with the lowest cost. This surface distance is computed using the fast-marching algorithm as in Allen and Arkolakis (2014), and it takes into account natural geographic features of the route from i to j. Using $W^s_{ij,t}$ to denote a vector of variables reflecting variable trade costs, we parameterize the variable non-tariff transport-cost component as:

$$\theta \ln \left(\tau^s_{ij,t}\right) = W^s_{ij,t}\omega. \tag{50}$$

$W^s_{ij,t}$ includes the following variables which vary across the tuples $\{sijt\}$: an unweighted average of antidumping provisions; an unweighted average of countervailing measures; an unweighted average of import licensing measures; an unweighted average of quantitative restrictions; an unweighted average of safeguard measures; an unweighted average of sanitary and phytosanitary standards; an unweighted average of sanitary and phytosanitary measures (with specific trade concern); an unweighted average of special safeguards;[16] an unweighted average of state trading enterprises; an unweighted average of technical barriers to trade; an unweighted average of technical barriers to trade (with specific trade concern); an unweighted average tariff rate quota; an unweighted average of export subsidies; binary indicators for free-trade-area membership for each year separately (notice that this relates to the effects of such agreements after tariffs); the services-trade-restrictiveness index for services of the exporter; the services-trade-restrictiveness index for services of the importer; the log fast-marching-distance (i.e., pure distance-transport) costs for each sector and year, a constant, and a measure of uncertainty.[17] Accordingly, some of the elements in the parameter vector ω reflect sector-country-specific elements of variable trade costs.

Moreover, we define fixed market-access costs as follows:

$$\ln\left(f_{ij,t}^{s}\right)=\left(\frac{\theta^{s}}{\sigma^{s}-1}-1\right)^{-1}\left(\kappa_{ij,t}^{s}-\theta\ln\left(\tau_{ij,t}^{s}\right)\right). \tag{51}$$

Then, we parameterize the scaled fixed-cost term in equation (49) as obtained from (51) as

$$\left(\frac{\theta^{s}}{\sigma^{s}-1}-1\right)\ln\left(f_{ij,t}^{s}\right)=Z_{ij,t}^{s}\zeta+\varepsilon_{ij,t}^{s}, \tag{52}$$

where $Z_{ij,t}^{s}$ is a vector of observable variables that we relate to fixed market-access costs of firms in market (country) i to j. These include: a vector of ones on which a constant is estimated; a binary indicator between i and j for land adjacency; a binary indicator between i and j for common ethnic language; a binary indicator between i and j for a colonial relationship; a binary indicator between i and j for a common currency; a binary indicator between i and j for a common religion; and the term $\varepsilon_{ij,t}^{s}$, a residual, which we assume to

[16] Regarding the sanitary and phytosanitary measures, we should acknowledge that not all countries systematically notify their draft measures.

[17] We use tariff waters to calculate bilateral uncertainty variables as: $tw_{ij,t}^{s}=D_{ij,t}\ln(1+w_{i,t}^{s}+w_{j,t}^{s})$, where $D_{ij,t}$ is a dummy for the absence of free trade agreements and $w_{i,t}^{s}$ and $w_{j,t}^{s}$ are tariff waters of the exporter and importer, respectively.

capture the unobservable part of the fixed market-access costs.[18]

When using the aforementioned variables together, we end up with a sample of 885,868 sector-country-pair-year observations. The explanatory power of $W^s_{ij,t}$ and $Z^s_{ij,t}$ – i.e., the observable variables behind non-tariff trade and market-access costs – together is about 7%. Hence, more than 90% of the variation in the estimate of overall log scaled non-tariff trade costs, $\widehat{\kappa}^s_{ij,t}$, is attributed to the unobservable component of fixed costs.[19]

In a first step, we describe moments of the distribution of the estimates in the data pertaining to three composite variables: $\widehat{\kappa}^s_{ij,t}$; $\widehat{\ln\left(\tau^s_{ij,t}\right)}$; and $\widehat{\ln\left(f^s_{ij,t}\right)}$. For the sake of brevity, we report on the 5-th, 10-th, 25-th, 50-th, 75-th, 90-th, and 95-th percentiles along with the corresponding number of observations for which the variables can be computed.

Table 6: *Percentiles of Various Trade-Cost Aggregates*

Percentile	$\kappa^s_{ij,t}$	$\ln\left(\tau^s_{ij,t}\right)$	$\ln\left(f^s_{ij,t}\right)$
5%	1.41	0.58	-6.33
10%	3.04	0.67	-1.00
25%	4.89	0.78	4.13
50%	6.86	0.90	10.00
75%	9.10	1.06	17.90
90%	11.54	1.26	28.08
95%	13.27	1.44	36.04
Observations	885,868	885,868	885,094

The results are summarized in Table 6, and they suggest the following insights. First of all, the median value of the estimate of $\kappa^s_{ij,t}$ is about 6.9 which is quite high. Clearly, if exclusively tariffs would matter for all trade costs, then that estimate would be zero.

[18]We fully admit that the distinction between proxy variables for variable versus fixed trade costs is debatable. However, some of the evidence in earlier work at least suggests that cultural factors such as language-related variables induce effects on micro-level trade flows which suggest that culture and language work more along the lines of fixed than variable costs (see, e.g., Egger and Lassmann, 2015). In any case, the provided codes allow the interested reader to make changes to the adopted assumptions.

[19]One note appears important with regard to the explanatory power of the model explaining "residual" (non-tariff) trade costs. Notice that this measure is obtained after conditioning on exporter-sector-time fixed effects, on total expenditures per importer-sector-time, as well as on scaled bilateral tariffs. Hence, the obtained measure $\kappa^s_{ij,t}$ should be interpreted as a within (exporter-sector-time, importer-sector-time, and tariffs) variable and the model R^2 can, hence, not be compared to other studies which report on the overall explanatory power of gravity models (including exporter-sector-time, importer-sector-time, as well as tariffs).

However, the estimated median value suggests that the non-tariff trade-cost part is large relative to tariffs. Especially, overall trade costs in the upper tail are substantial. In the lower tail of the distribution, we find observations, whose trade is facilitated by the measures in $W_{ij,t}^{s}$ to a nontrivial extent. The second column in the table refers to the estimate of $\ln\left(\tau_{ij,t}^{s}\right)$ and suggests that also variable non-tariff trade costs are non-negligible at the median, where the estimate exceeds a value of 0.89. Again, if variable non-tariff barriers were irrelevant, that estimate would be zero throughout the distribution. The estimates take on values of about 0.58 and 1.44 between the 5-th and the 95-th percentiles of the distribution. The lion's share in overall trade and market-access costs is obviously contributed by fixed costs, as expected and as can be seen from the last column in the table. While fixed costs are close to zero for a small fraction of the observations, they take on values as high as about 10 in logs at the median and even higher in the upper tail of the distribution. Note that by construction from equation (52), the fixed costs include residual components of $\kappa_{ij,t}^{s}$.

In a next step we visualize the estimates of the composite, overall (variable and fixed net of tariffs), scaled trade cost parameter in logs, $\kappa_{ij,t}^{s}$, in Figure 5. We also visualize changes in the average variable and fixed trade costs over time by way of Figures 6 and 7. In all Figures 5-7, we present the results for the manufacturing and services sectors separately.

These three figures clearly suggest that the total (net of tariffs) trade costs have been decreasing from 1995 to 2008 with a modest increase during the year of the global Economic and Financial Crisis. The overall level of total trade costs is higher for services than for the manufacturing goods, which is in line with findings from Egger, Larch and Staub (2012) and Anderson et al. (2015). This stems from the fact that variable trade costs in the latter sector have been substantially lower. On the other hand, Figure 7 suggests that the fixed costs are generally higher for manufacturing sectors than for services.[20]

[20]Sector 35 dubbed "Private Households with Employed Persons" is an outlier where many flows are recorded as zeros. We do not exclude it when calculating average trade costs and decomposing them by different groups in this section.

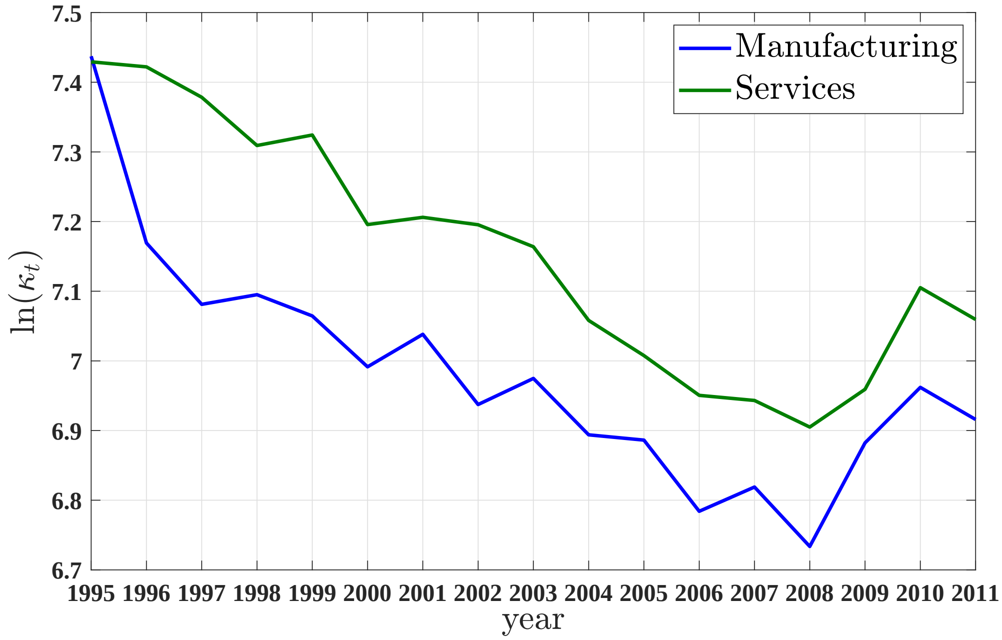


Fig. 5: *Total Trade Costs*

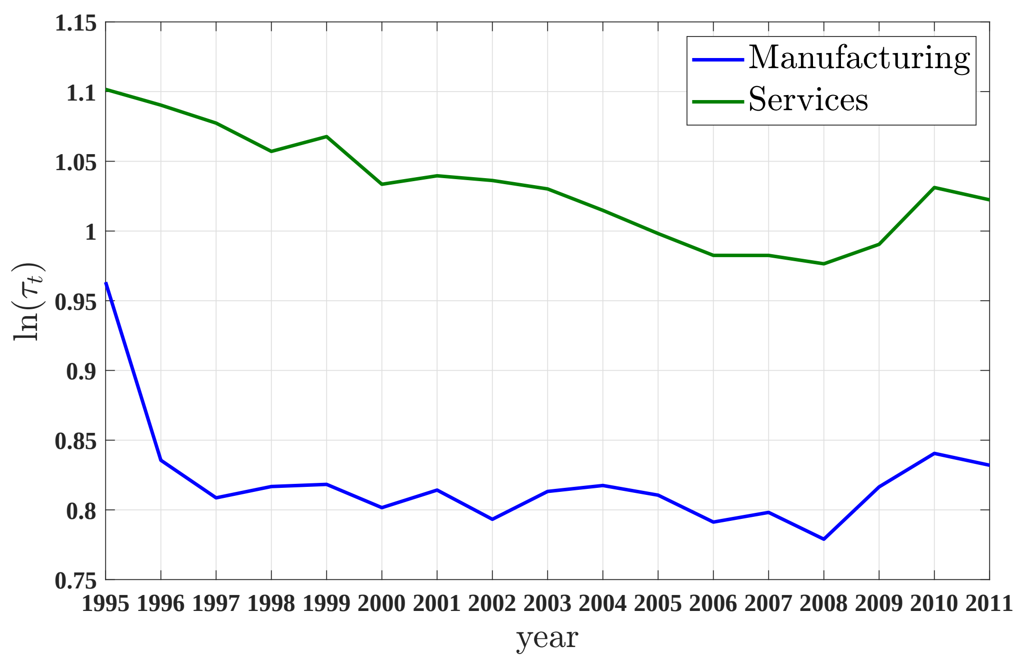


Fig. 6: *Variable Trade Costs*

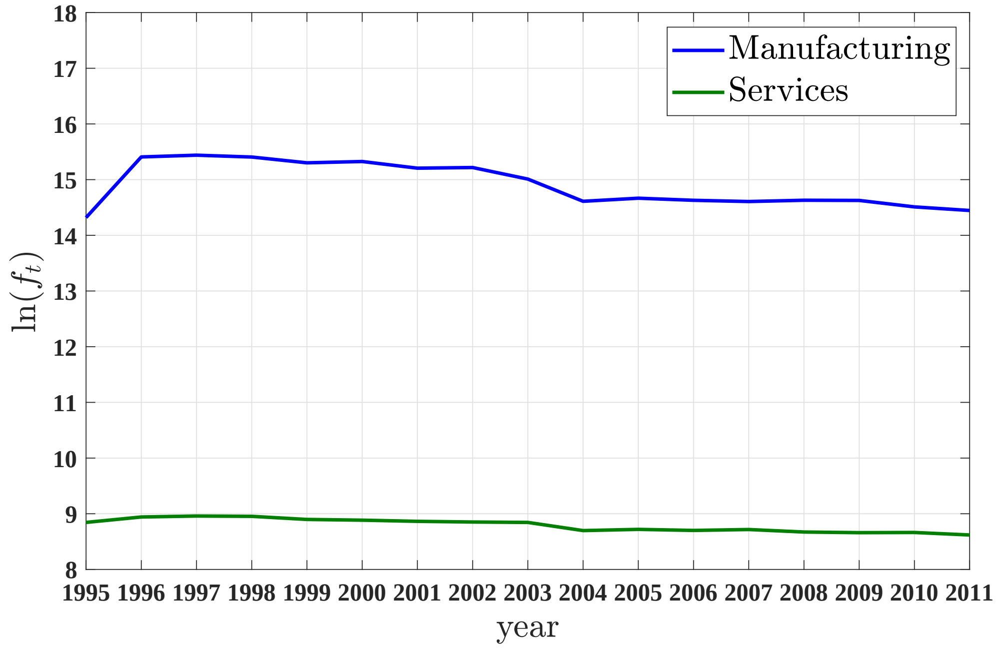


Fig. 7: *Fixed Trade Costs*

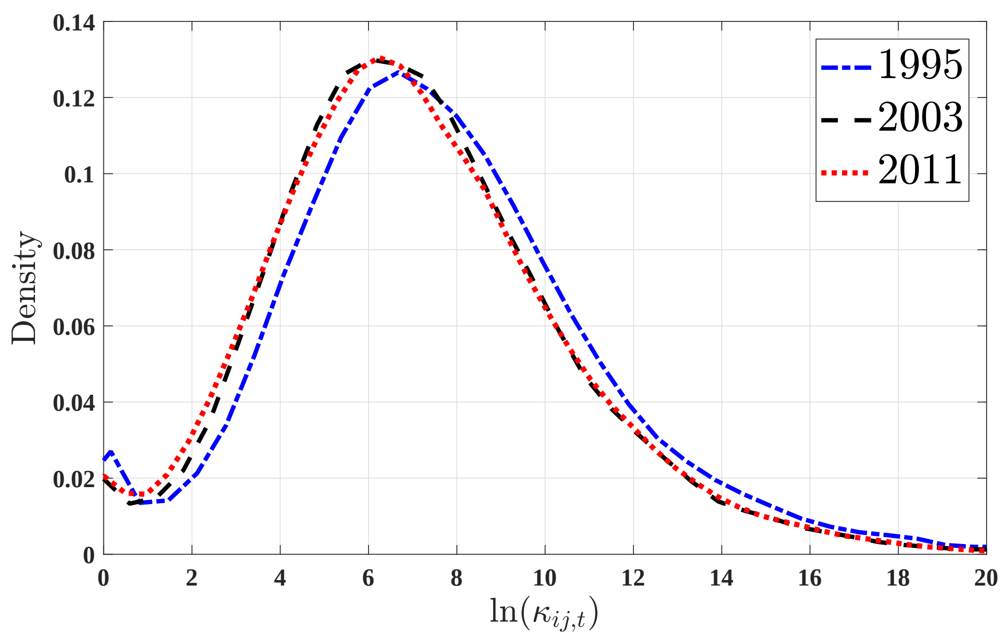


Fig. 8: *Density of Total Trade Costs: Manufacturing Sectors*

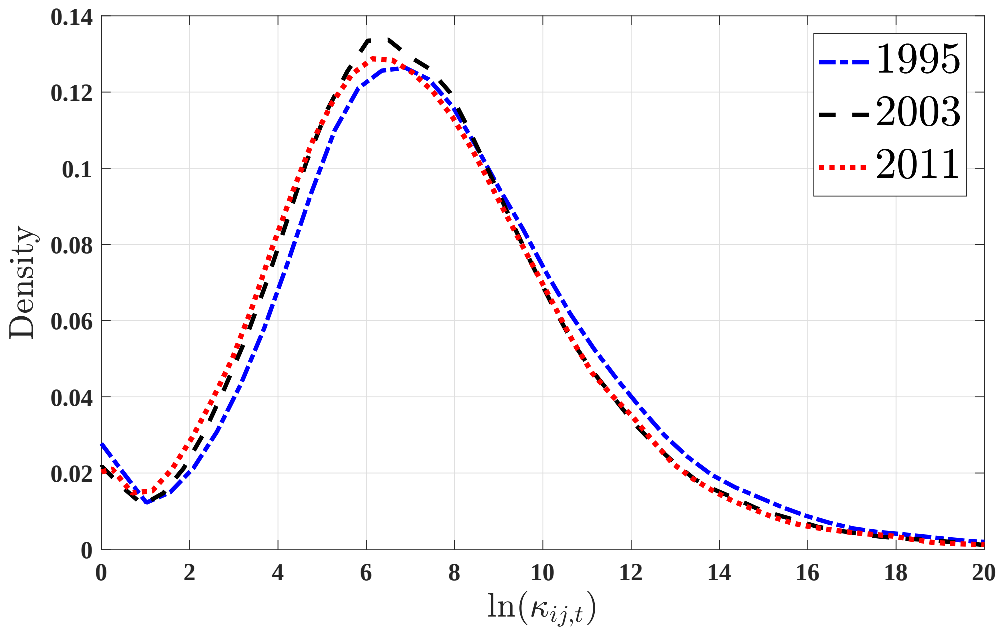


Fig. 9: *Density of Total Trade Costs: Service Sectors*

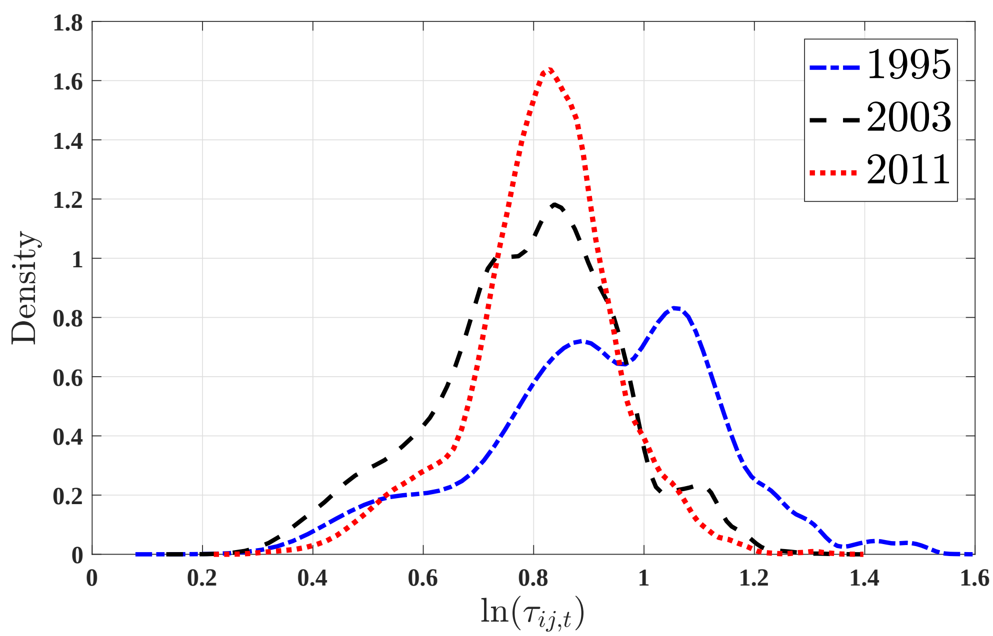


Fig. 10: *Density of Variable Trade Costs: Manufacturing Sectors*

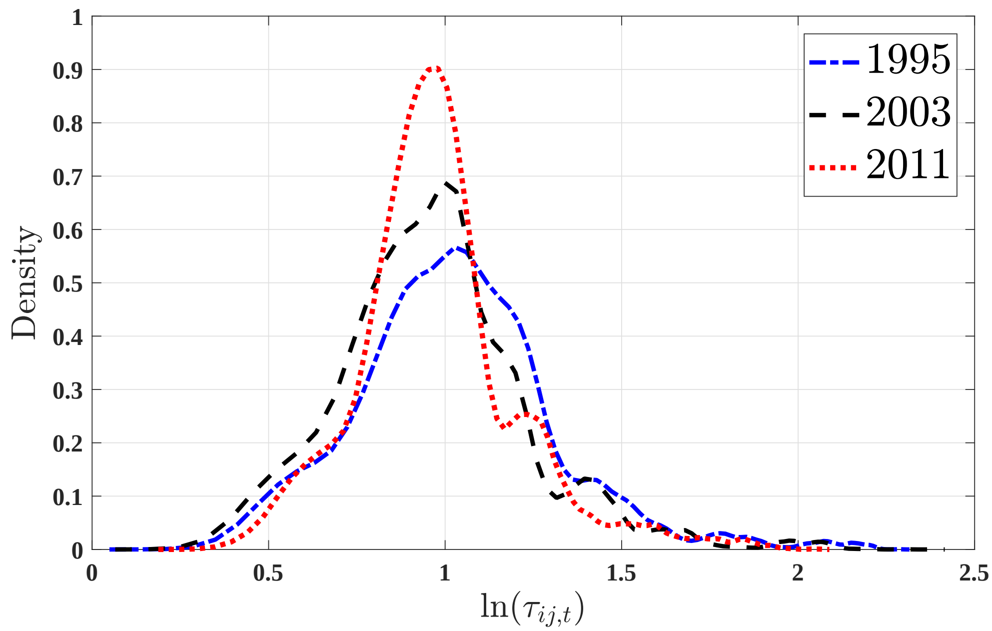


Fig. 11: *Density of Variable Trade Costs: Service Sectors*

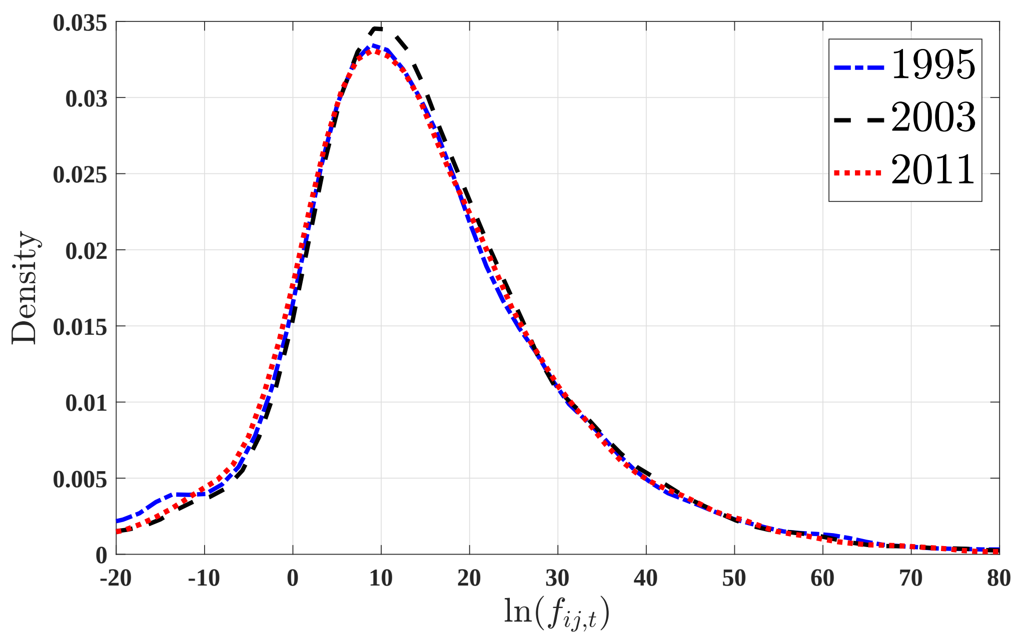


Fig. 12: *Density of Fixed Trade Costs: Manufacturing Sectors*

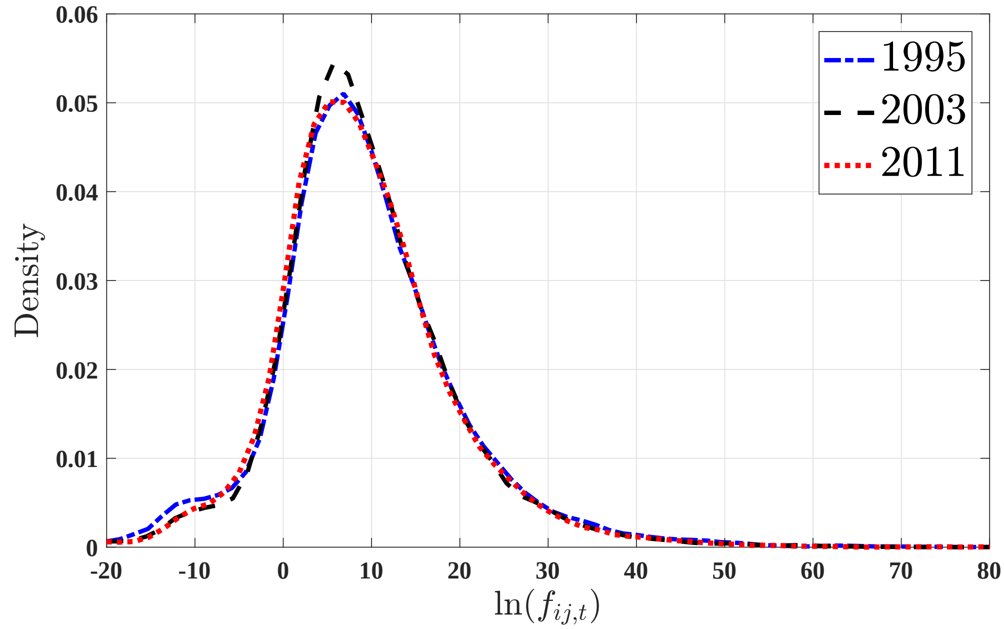


Fig. 13: *Density of Fixed Trade Costs: Service Sectors*

Figures 8-12 display the estimates of $\widehat{\kappa}^s_{ij,t}$, $\widehat{\tau}^s_{ij,t}$, and $\widehat{f}^s_{ij,t}$ by way of density plots for all country pairs and for three year sub-periods of the data, namely 1995, 2003, and 2011. Figure 8 and 9 suggest that there were reductions in total trade costs in both manufacturing and services sectors across the considered years. Figures 10 and 11 suggest much of this change came from the fact that the waists of the distributions of variable trade costs have become narrower over time. This points to certain convergence in variable trade costs across different pairs of countries. On the other hand, fixed trade costs have remained relatively stable overtime as is evident from Figures 12 and 13.[21] One has to keep in mind that Figures 5-13 are based on normalized values of scaled total trade costs and their components. Hence, what we can assess here are only changes in dispersions of normalized trade costs and their components. This is due to the fact that a number of sector-country-time normalizations are involved. Our estimates are obtained by imposing SJT normalizations (with S sectors, J countries, and T time periods) and conditioning on $S(J-1)T$ sector-country-time fixed effects. This is a general feature of calibrated trade costs as outlined in Egger and Nigai (2015). However,

[21]Notice that the fixed costs in Figure 12 are in logs. Hence, negative log values imply small – but still positive – levels of fixed costs of firms in i to enter market j in year t.

there is still variation left in trade costs within countries, sectors, and time that permits disentagling the role of different factors behind them.

5.3 Heterogeneity of Trade Costs by Income Level, Worker Type (Skills) and Firm Type

In this section, we aggregate total trade costs and its components as obtained before (i.e., using the data and parameters estimated in earlier subsections) along three important dimensions. In Subsection 5.3.1, we aggregate total costs by the income levels of consumers in importing countries. In Subsection 5.3.2, we aggregate trade costs by the skill type of workers in exporting countries. Finally, in Subsection 5.3.3 we look at how the firm size distribution is related to total, variable, and fixed trade costs.

5.3.1 Heterogeneity of Trade Costs Across Income Levels

Consumer expenditure shares on goods from different sectors vary with the income level. This means that the relative weights of sectoral trade costs (both variable and fixed) vary across different consumer groups. In this Subsection, we employ a model of non-homothetic preferences from Egger and Nigai (2018) to (1) calibrate expenditure shares for five consumer groups in each country across different years, and (2) use these expenditure shares to calculate consumer-group-specific trade costs.

For this, we employ data on wages from the WIOD Socio-Economic Accounts and the parameters from Egger and Nigai (2018) to calibrate expenditure shares of five consumer-group quintiles $g = (1; 2; 3; 4; 5)$, where $g = 1$ is the lowest-income quintile and $g = 5$ the highest-income quintile, in country i and year t on outputs from sector s and denote it as $\upsilon^{s}_{i,t}(g)$. Hence, we consider five income-related population quantiles in each country and year.[22]Based on these quantiles, we can calculate income-group-specific $k =$ (variable, fixed) trade costs

[22]We do not consider taxes and base our classification on WIOD reported wages. Detailed data on personal income tax schedules and their progressivity it outside of the scope this work.

as:[23]

$$k_{i,t}(g) = \prod_{s=1}^{s=35} \left(\frac{1}{J} \sum_{j} k_{ji,t}^{s} \right)^{v_{i,t}^{s}(g)}, \text{ where } \sum_{s} v_{i,t}^{s}(g) = 1. \tag{53}$$

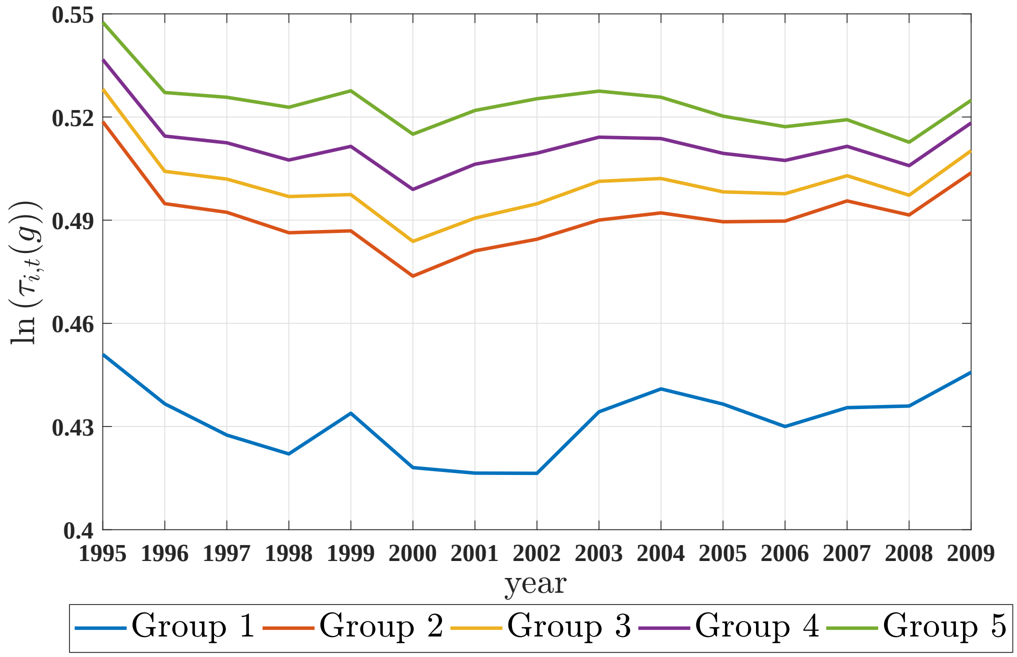


Fig. 14: *Decomposition of Variable Trade Costs by Income Groups*

[23]We rely on simple averages rather than consumption-value-weighted averages here.

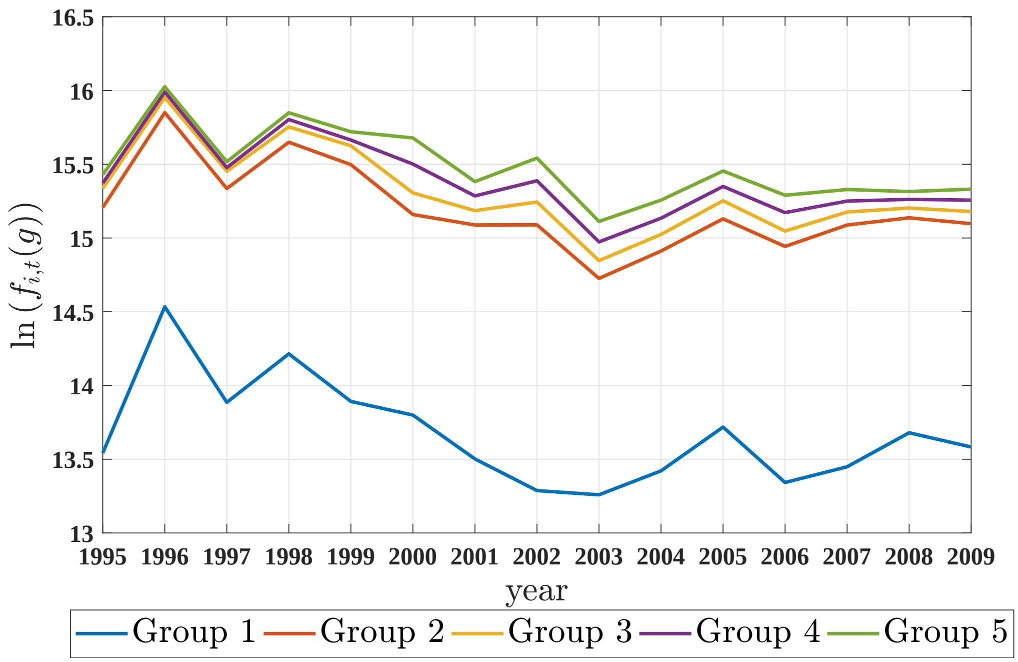


Fig. 15: *Decomposition of Fixed Trade Costs by Income Groups*

Table 7: *Trade Costs (in logs) Decomposed by Income Groups*

TRADE COST	Variable					Fixed				
INCOME GROUP	1	2	3	4	5	1	2	3	4	5
ISO										
AUS	0.58	0.67	0.68	0.68	0.68	14.63	15.86	15.90	15.93	15.98
AUT	0.54	0.54	0.54	0.54	0.55	14.21	14.25	14.27	14.28	14.31
BEL	0.52	0.53	0.53	0.53	0.53	13.54	13.69	13.70	13.72	13.74
BGR	0.30	0.38	0.40	0.43	0.45	11.71	12.55	12.69	12.99	13.21
BRA	0.03	0.45	0.50	0.54	0.59	1.98	18.69	19.65	20.49	21.37
CAN	0.56	0.57	0.58	0.58	0.58	17.43	17.64	17.72	17.74	17.78
CHN	0.17	0.29	0.30	0.36	0.40	5.97	10.99	11.09	10.47	10.11
CYP	0.53	0.56	0.57	0.57	0.57	17.23	17.93	17.99	18.06	18.15
CZE	0.44	0.44	0.45	0.45	0.46	15.36	15.46	15.49	15.53	15.64
DEU	0.49	0.50	0.50	0.50	0.51	13.64	13.73	13.75	13.77	13.79
DNK	0.54	0.55	0.55	0.55	0.55	17.02	17.11	17.13	17.14	17.17
ESP	0.51	0.55	0.55	0.55	0.55	13.86	14.36	14.39	14.43	14.46
EST	0.40	0.45	0.46	0.46	0.47	14.88	15.27	15.35	15.39	15.48
FIN	0.55	0.56	0.56	0.56	0.56	15.62	15.69	15.72	15.73	15.76
FRA	0.53	0.53	0.53	0.54	0.54	12.98	13.02	13.03	13.05	13.08
GBR	0.56	0.56	0.57	0.57	0.57	14.25	14.31	14.33	14.36	14.40
GRC	0.53	0.54	0.55	0.55	0.55	14.81	14.94	14.99	15.05	15.12
HUN	0.42	0.44	0.45	0.45	0.46	13.44	13.55	13.58	13.61	13.65
IDN	0.15	0.26	0.30	0.38	0.45	7.15	12.40	12.54	12.80	12.93
IND	0.21	0.22	0.22	0.33	0.42	11.18	12.26	12.82	13.92	14.16
IRL	0.54	0.55	0.55	0.55	0.55	14.34	14.43	14.46	14.48	14.50
ITA	0.53	0.54	0.54	0.55	0.55	14.37	14.58	14.59	14.61	14.64
JPN	0.59	0.66	0.67	0.67	0.67	17.67	19.22	19.29	19.33	19.40
KOR	0.52	0.61	0.62	0.62	0.63	15.62	17.10	17.24	17.31	17.40
LTU	0.38	0.39	0.40	0.41	0.41	14.65	14.70	14.68	14.68	14.66
LUX	0.52	0.53	0.53	0.53	0.53	17.20	17.28	17.30	17.32	17.34
LVA	0.32	0.43	0.44	0.45	0.47	14.90	17.30	17.61	17.78	18.08
MEX	0.15	0.51	0.57	0.59	0.61	9.25	17.44	18.39	18.73	19.10
MLT	0.32	0.44	0.44	0.44	0.45	17.70	18.95	18.98	19.01	19.05
NLD	0.51	0.54	0.54	0.54	0.54	13.19	13.68	13.72	13.73	13.77
POL	0.46	0.48	0.49	0.49	0.50	13.34	13.75	13.83	13.90	14.00
PRT	0.52	0.53	0.54	0.54	0.55	16.92	17.09	17.15	17.20	17.29
ROU	0.32	0.39	0.39	0.40	0.42	10.17	10.27	10.30	10.30	10.32
RUS	0.13	0.30	0.35	0.37	0.39	7.08	12.72	12.65	12.61	12.59
SVK	0.41	0.44	0.45	0.45	0.46	14.45	14.69	14.76	14.80	14.94
SVN	0.48	0.48	0.48	0.48	0.49	15.85	15.91	15.93	15.95	16.00
SWE	0.53	0.53	0.54	0.54	0.54	15.18	15.22	15.23	15.24	15.27
TPKM	0.57	0.58	0.58	0.59	0.59	14.43	14.59	14.66	14.72	14.83
TUR	0.23	0.45	0.45	0.46	0.48	13.01	18.24	18.32	18.49	18.77
USA	0.68	0.69	0.69	0.69	0.69	16.78	16.89	16.99	17.02	17.07
AVRG	0.43	0.49	0.50	0.51	0.52	13.67	15.19	15.31	15.39	15.48

Figures 14 and 15 summarize the corresponding results and suggest that there is heterogeneity in both variable and fixed costs across different income groups. Consumer groups with higher income generally face higher trade costs. This is due to the fact that richer households tend to spend a higher share of their income on services. Since services trade costs are relatively higher, richer consumers generally bear larger trade costs on average. This holds for both variable and fixed trade costs. We report country-specific averages (in logs) for 1995-2009 across all sectors in Table 7 to complement the figures.[24]

5.3.2 Heterogeneity of Trade Costs Across Skill Types

The previous subsubsection alluded to a heterogeneity of trade costs on the demand side by focusing on consumers in different income groups in a country. The purpose of the present subsubsection is to shed light on the heterogeneity of trade costs on the supply side by differentiating between workers of different formal skill type. There is a certain degree of heterogeneity across different sectors in terms of the skill types of employed workers. In this subsection, we decompose variable and fixed costs faced by low-skilled, medium-skilled and high-skilled workers when weighting trade costs on the supply side for these three groups of workers. For that let us first define the share of workers of type g = (low-skilled, medium-skilled, high-skilled) employed in country i, sector s, and year t as $\omega^s_{i,t}(g)$. Then, we calculate average variable and fixed trade costs of workers of type g as:[25]

$$k_{i,t}(g) = \sum_{s=1}^{s=35} \omega^s_{i,t}(g) \left(\frac{1}{J} \sum_j k^s_{ij,t} \right) \text{ for k = (variable, fixed trade costs) .} \tag{54}$$

[24] Due to the limited availability of expenditure data, we can only consider 1995-2009 in this analysis.

[25] Again, we rely on simple averages rather than consumption-value-weighted averages in this exercise.

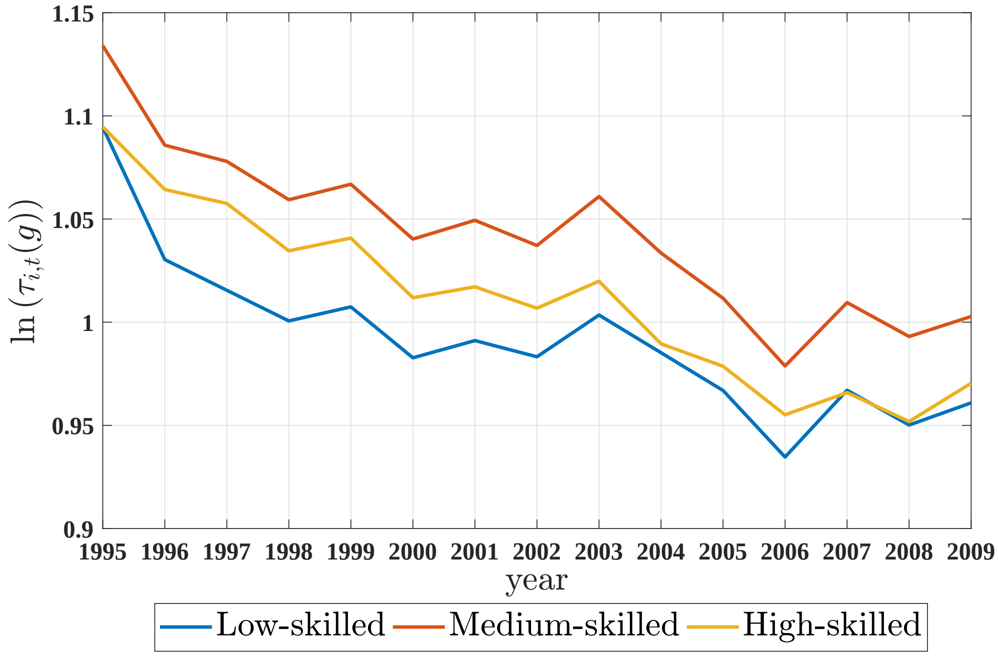


Fig. 16: *Decomposition of Variable Trade Costs by Skill Groups*

Fig. 17: *Decomposition of Fixed Trade Costs by Skill Groups*

Figures 16 and 17 summarize the evolution of skill-group-specific trade costs on the supply side for the average country covered over time. Consistent with the general pattern of a decline in trade costs, Figure 16 indicates that trade costs declined for all skill types. However, the same figure suggests that they declined somewhat more strongly for low-skilled and high-skilled workers than for medium-skilled ones, and they had been highest for medium-skilled workers throughout. The variable trade costs seem to have converged for the low- and high-skilled groups. As can be seen from Figure 17, in terms of fixed costs we do not see substantial differences between skill-groups on the supply side. If at all, one may conclude that they are slightly lower for high-skilled workers.

While Figures 16 and 17 summarized the evolution of skill-group-specific trade costs on the supply side for the average country covered over time for all sectors jointly, Figures 18-21 break this information up into the one for manufacturing sectors only (Figures 18 and 19) and services sectors only (Figures 20 and 21).

A comparison of Figures 18-21 with Figures 16 and 17 suggests the following insights. First of all, the gap in variable trade cots, $\tau^s_{ij,t}$, between skill groups is smaller for manufactures than it is for services. Second, variable trade costs are very similar in levels as well as their decline for low- and middle-skilled workers, while they are considerably lower but decline similarly as with other skill groups for high-skilled workers. Third, the gap in fixed costs, $f^s_{ij,t}$, is larger across skill groups at the beginning and in the middle of the sample period, while there is some convergence in fixed trade costs across skill groups at the end of the sample period. Finally, the gap in fixed trade cots, $f^s_{ij,t}$, between skill groups is very small for services.

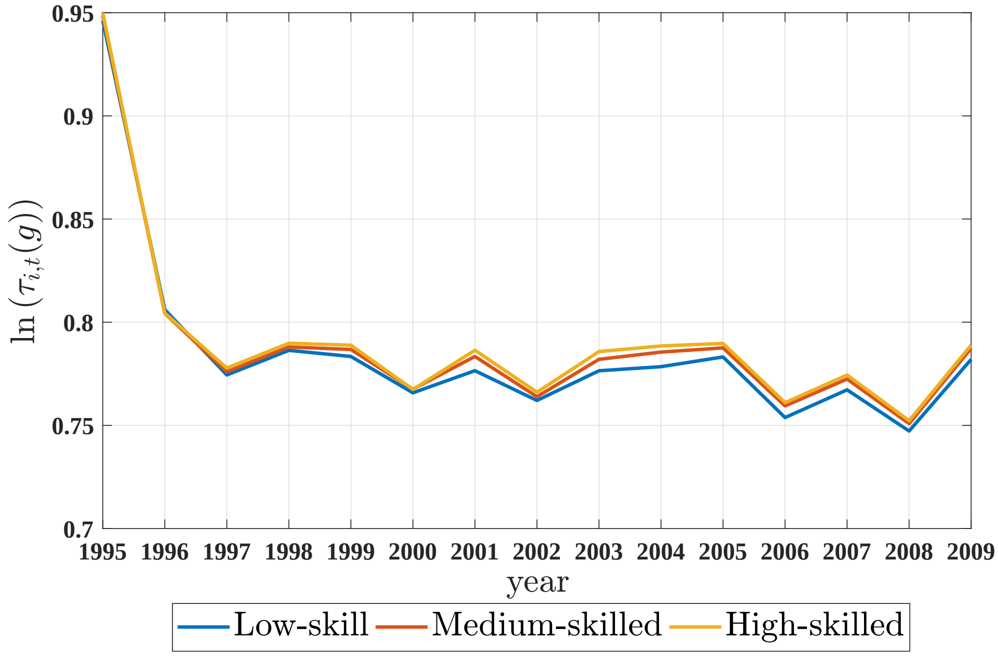


Fig. 18: *Decomposition of Variable Trade Costs by Skill Groups in Manufacturing*

Fig. 19: *Decomposition of Fixed Trade Costs by Skill Groups in Manufacturing*

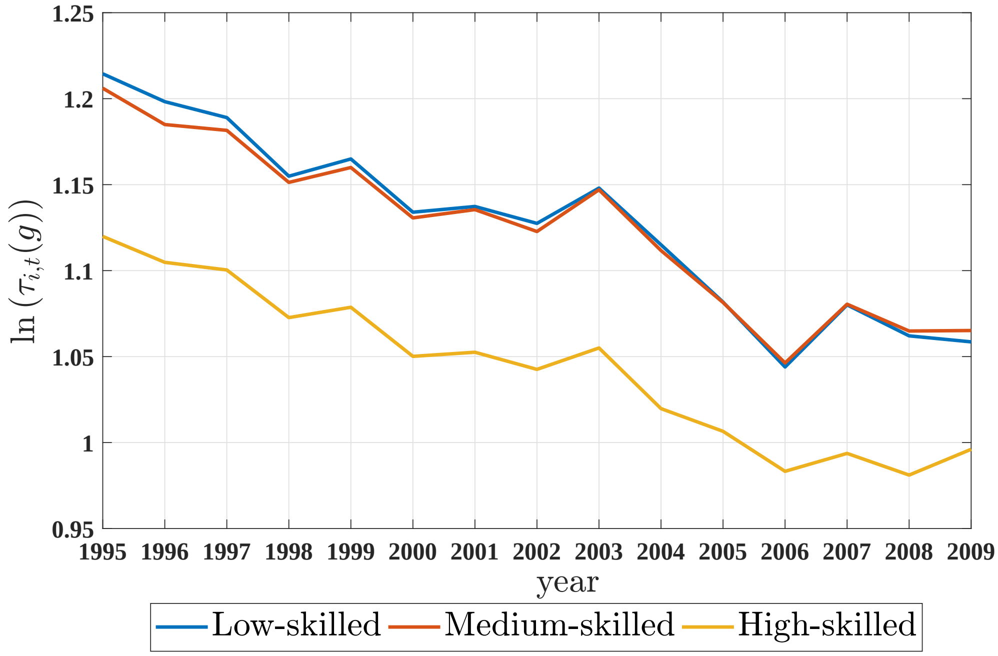


Fig. 20: *Decomposition of Variable Trade Costs by Skill Groups in Services*

Fig. 21: *Decomposition of Fixed Trade Costs by Skill Groups in Services*

Table 8 provides further details on skill-type-specific variable and fixed trade costs in the average year by country, when using $\{1, 2, 3\}$ to label the groups of low-skilled, medium-skilled, and high-skilled workers, respectively.

Table 8: *Trade Costs (in logs) Decomposed by Skill Groups*

TRADE COST	Variable			Fixed		
SKILL GROUP	1	2	3	1	2	3
ISO						
AUS	1.27	1.25	1.17	77.67	77.78	77.12
AUT	0.96	0.98	0.94	75.90	75.87	75.65
BEL	0.96	0.96	0.91	76.24	76.05	75.60
BGR	0.96	1.02	1.01	78.09	77.66	76.76
BRA	1.14	1.25	1.16	77.97	78.22	77.70
CAN	1.06	1.11	1.03	77.05	77.43	76.94
CHN	0.95	1.14	1.09	74.40	75.12	74.87
CYP	1.01	1.08	1.04	78.52	78.17	77.48
CZE	0.92	0.98	0.95	76.46	76.18	75.44
DEU	0.94	0.94	0.89	76.07	75.85	75.77
DNK	0.96	0.97	0.93	76.36	76.03	75.37
ESP	1.06	1.07	1.02	78.05	77.87	77.48
EST	0.96	1.00	1.01	77.26	77.00	76.43
FIN	1.01	1.01	1.00	77.49	77.51	77.15
FRA	0.95	0.97	0.94	75.43	75.46	75.05
GBR	1.00	1.00	0.95	72.30	72.21	71.90
GRC	1.02	1.10	1.03	77.44	77.35	76.75
HUN	0.92	1.01	0.97	77.83	77.59	76.76
IDN	1.05	1.11	1.08	77.46	77.80	76.90
IND	0.97	1.11	1.14	78.79	79.18	79.39
IRL	1.04	1.05	0.99	78.28	78.40	78.26
ITA	0.95	0.96	0.92	73.94	73.74	72.98
JPN	1.05	1.12	1.12	77.86	77.79	77.73
KOR	1.01	1.12	1.14	79.71	79.34	78.55
LTU	0.92	1.00	1.02	77.50	77.68	77.07
LUX	1.00	0.96	0.89	75.13	74.94	74.39
LVA	0.96	1.02	1.01	78.11	77.89	77.39
MEX	1.06	1.23	1.22	78.14	78.84	78.50
MLT	0.98	0.99	0.97	77.44	76.71	75.95
NLD	0.99	0.97	0.91	76.10	75.88	75.49
POL	0.83	0.93	0.95	72.10	72.67	72.05
PRT	1.03	1.07	1.01	79.15	78.73	77.98
ROU	0.92	1.00	0.97	77.28	77.13	76.42
RUS	0.82	0.89	0.90	78.14	78.27	77.63
SVK	0.92	0.99	0.96	77.07	76.96	76.42
SVN	0.85	0.97	0.94	76.33	76.09	75.45
SWE	0.96	0.97	0.94	68.74	68.54	67.66
TUR	0.97	1.05	1.01	78.31	78.51	77.88
TPKM	1.08	1.12	1.08	79.41	79.06	78.45
USA	1.15	1.14	1.08	76.18	76.42	76.79
AVRG	0.99	1.04	1.01	76.79	76.75	76.24

5.3.3 Firm-size Decomposition

In this subsection, we decompose trade costs by firm size. For that, we use data from the OECD Structural and Demographic Business Statistics which classifies firms into five different size classes:

- Group 1: 1-9 persons employed,
- Group 2: 10-19 persons employed,
- Group 3: 20-49 persons employed,
- Group 4: 50-249 persons employed,
- Group 5: 250 and more persons employed.

Unfortunately, the data are not available for all countries, sectors, and years. However, we can use the prediction of the underlying structural-theoretical model which suggests that the number of firms in a given sector is proportional to θ^s-normalized employment. Hence, in the first step we predict the number of operating firms in each country, sector, and year using the following regression:

$$\ln(N^s_{i,t}(g)) = \alpha\theta^s + \sum_{g=1}^{g=5} \alpha^s ln\left(L^s_{i,t}\right). \tag{55}$$

We then use predictions of $N^s_{i,t}(g)$ to decompose variable and fixed trade costs according to firm size. Let us define the share of firms of type $g = (1, 2, 3, 4, 5)$ operating in country i, sector s, and year t as $\omega^s_{i,t}(g)$. Then, we calculate average firm-size-group-specific variable and fixed trade costs of workers of type g as:

$$k_{i,t}(g) = \sum_{s=1}^{s=35} \omega^s_{i,t}(g) \left(\frac{1}{J}\sum_{j} k^s_{ij,t}\right) \text{ for k = (variable, fixed trade costs)}. \tag{56}$$

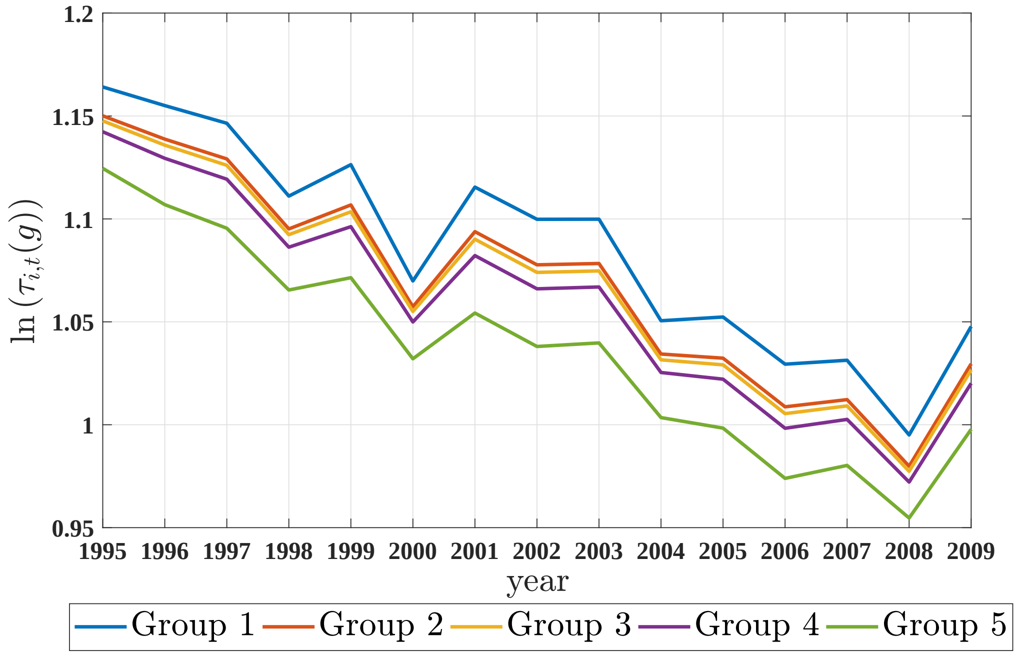


Fig. 22: *Decomposition of Variable Trade Costs by Firm Size*

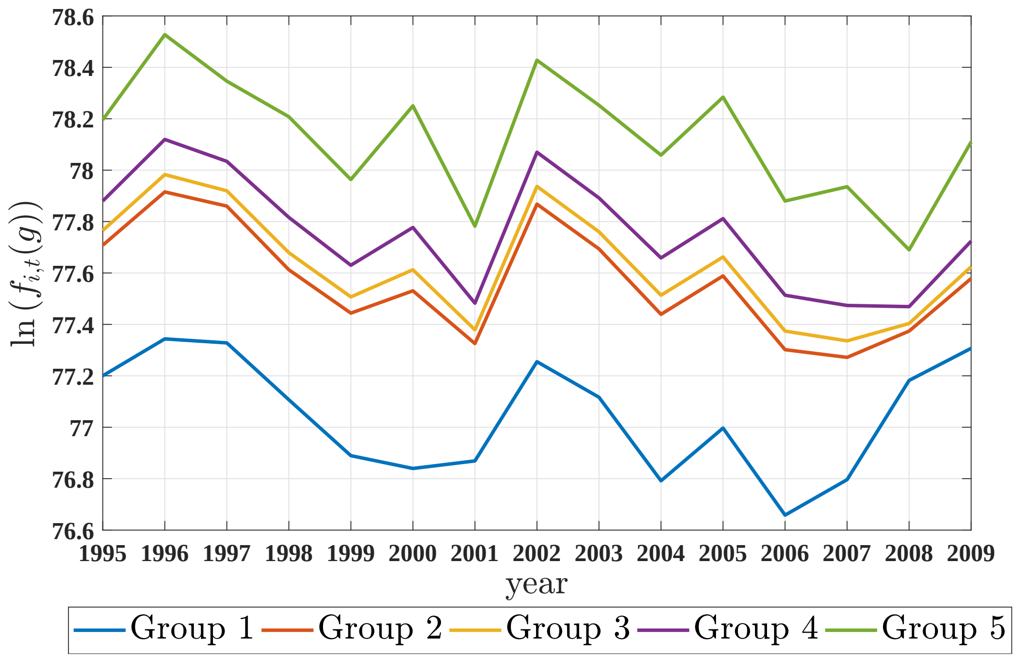


Fig. 23: *Decomposition of Fixed Trade Costs by Firm Size*

Figures 22 and 23 summarize the corresponding results of trade costs for the five size classes of firms. Interestingly, these figures indicate that the variable trade costs are lowest throughout for the largest firms and highest for the smallest ones, while the opposite is true for fixed costs.

Figures 24-27 break the same information as in Figures 22 and 23 up into the one for manufacturing sectors only (Figures 24 and 25) and services sectors only (Figures 26 and 27).

We can highlight the following insights gained from a comparison of Figures 24-27 with Figures 22 and 23. First of all, the gap in variable trade cots, $\tau_{ij,t}^{s}$, and the ranking of associated levels is similar between firm-size groups in manufacturing and services separately as with all sectors together. Second, variable trade costs change in a largely similar way across firm-size groups as is the case for all sectors on average. Third, the gap in fixed costs, $f_{ij,t}^{s}$, is also similar across firm-size groups for manufactures as for all sectors together, except for the end of the sample period, where we see a larger degree of convergence across firm size groups in manufacturing than on average. Finally, the gap in fixed trade cots, $f_{ij,t}^{s}$, between firm-size groups is much more similar for services than both for manufacturing alone and for all sectors together.

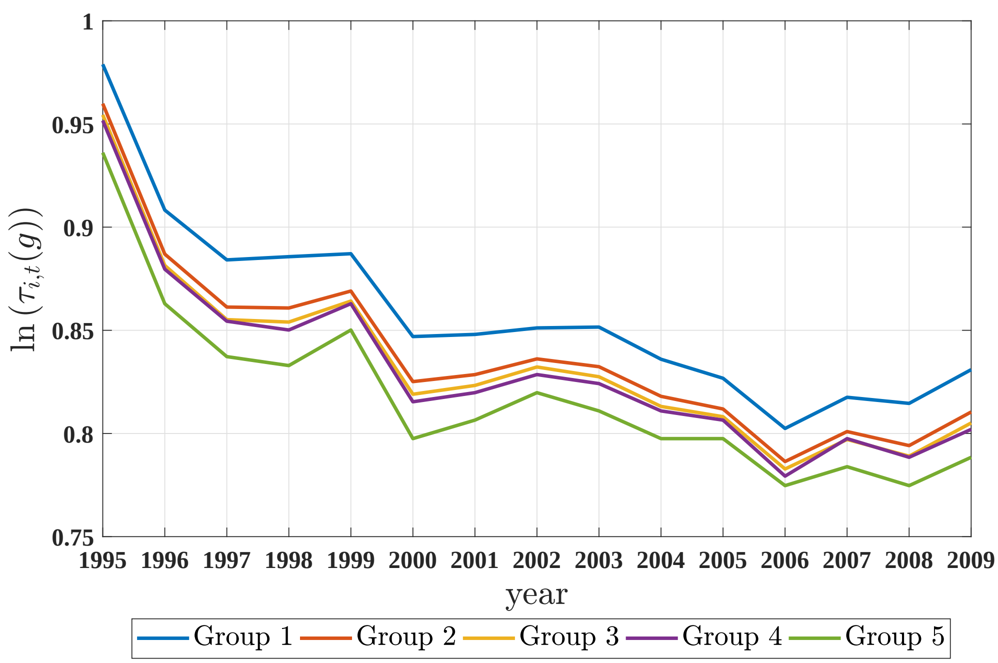


Fig. 24: *Decomposition of Variable Trade Costs by Firm Size in Manufacturing*

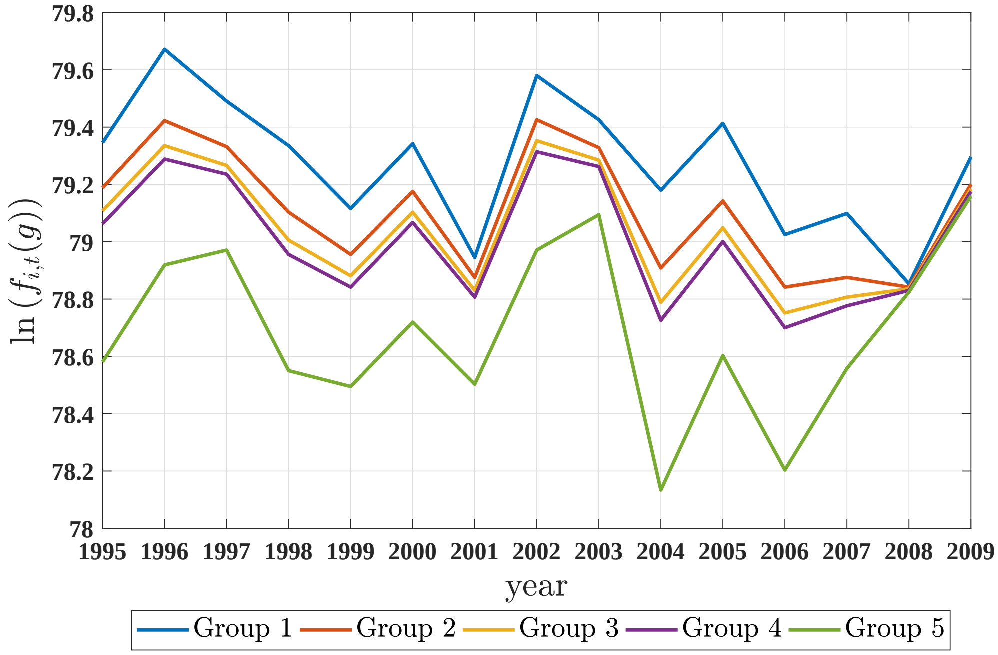


Fig. 25: *Decomposition of Fixed Trade Costs by Firm Size in Manufacturing*

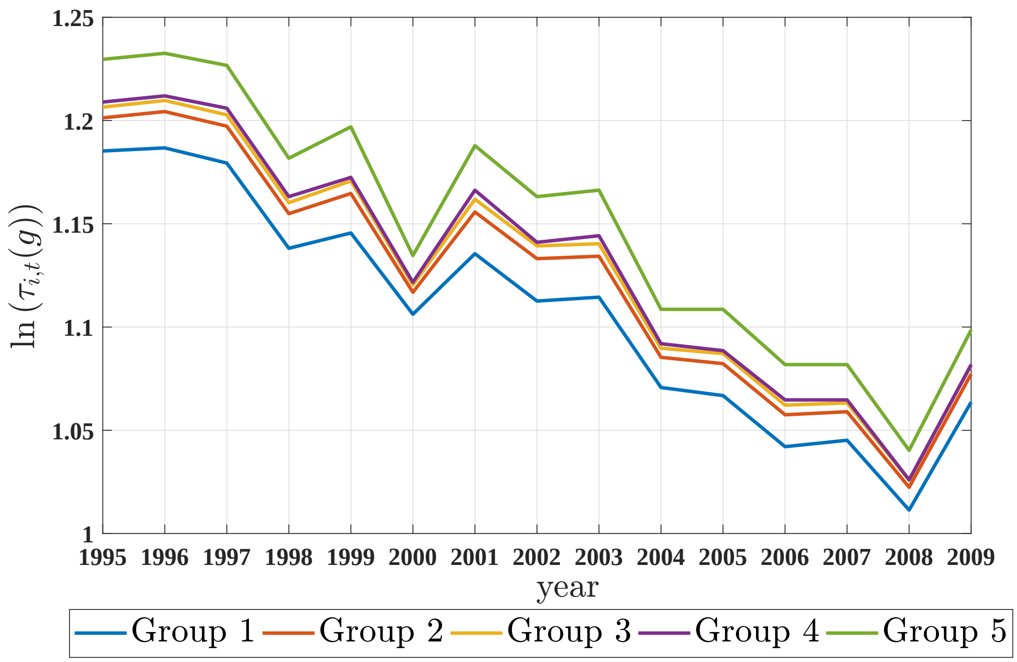


Fig. 26: *Decomposition of Variable Trade Costs by Firm Size in Services*

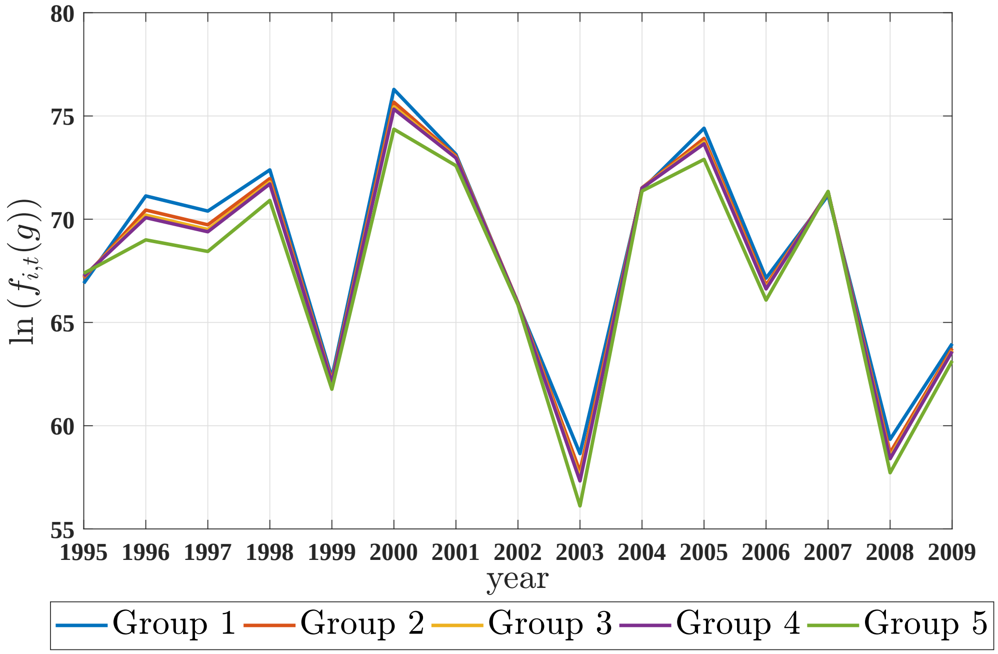


Fig. 27: *Decomposition of Fixed Trade Costs by Firm Size in Services*

Again, Table 9 sheds light on this decomposition by country in the average year.

Table 9: *Trade Costs (in logs) Decomposed by Firm Size*

TRADE COST	Variable					Fixed				
FIRM GROUP	1	2	3	4	5	1	2	3	4	5
ISO										
AUS	1.36	1.30	1.30	1.28	1.23	76.89	77.67	77.77	77.97	78.59
AUT	1.02	1.00	0.99	0.99	0.97	71.77	72.47	72.55	72.70	73.13
BEL	0.99	0.98	0.98	0.97	0.96	72.23	72.94	73.04	73.23	73.87
BGR	1.02	1.03	1.03	1.03	1.03	77.20	77.16	77.15	77.12	76.97
BRA	1.29	1.25	1.24	1.23	1.19	77.85	78.37	78.43	78.54	78.83
CAN	1.20	1.15	1.14	1.13	1.10	77.01	77.45	77.50	77.61	77.97
CHN	1.13	1.16	1.16	1.16	1.14	76.68	77.45	77.52	77.66	77.99
CYP	1.14	1.11	1.11	1.10	1.06	76.98	77.95	78.07	78.32	79.05
CZE	1.01	0.99	0.99	0.98	0.96	75.45	75.50	75.50	75.50	75.42
DEU	0.98	0.96	0.95	0.94	0.92	74.84	75.34	75.40	75.50	75.77
DNK	0.99	0.98	0.98	0.97	0.95	76.87	77.29	77.34	77.42	77.58
ESP	1.08	1.05	1.05	1.04	1.01	76.38	76.94	77.00	77.12	77.41
EST	1.05	1.02	1.02	1.01	0.99	75.00	75.55	75.61	75.74	76.12
FIN	1.04	1.03	1.02	1.02	1.00	75.69	76.60	76.71	76.94	77.68
FRA	0.99	0.98	0.98	0.97	0.96	72.46	72.94	73.00	73.10	73.35
GBR	1.02	1.00	1.00	1.00	0.98	76.26	76.77	76.83	76.94	77.23
GRC	1.10	1.07	1.06	1.06	1.02	76.00	76.88	76.98	77.18	77.72
HUN	1.05	1.02	1.02	1.01	0.99	75.73	76.29	76.34	76.46	76.75
IDN	1.16	1.18	1.17	1.17	1.14	78.03	78.99	79.09	79.28	79.76
IND	1.18	1.21	1.21	1.20	1.18	77.80	78.37	78.44	78.58	78.93
IRL	1.07	1.04	1.04	1.03	1.00	75.73	76.77	76.91	77.21	78.18
ITA	1.03	1.01	1.00	1.00	0.97	75.02	75.52	75.58	75.69	75.97
JPN	1.21	1.17	1.17	1.16	1.13	77.96	78.37	78.43	78.54	78.92
KOR	1.22	1.19	1.18	1.17	1.14	77.50	77.96	78.01	78.10	78.35
LTU	1.05	1.02	1.02	1.01	0.98	77.23	77.95	78.03	78.19	78.65
LUX	1.01	0.99	0.99	0.99	0.96	76.34	77.17	77.27	77.47	78.06
LVA	1.04	1.02	1.01	1.00	0.98	75.72	76.65	76.77	77.01	77.78
MEX	1.29	1.25	1.24	1.23	1.19	77.42	77.86	77.91	78.01	78.28
MLT	1.03	1.03	1.03	1.02	1.01	76.98	77.50	77.57	77.70	78.08
NLD	1.02	0.99	0.99	0.98	0.96	74.70	75.50	75.59	75.76	76.20
POL	0.97	0.97	0.96	0.96	0.95	76.18	76.74	76.81	76.93	77.25
PRT	1.09	1.07	1.07	1.06	1.04	77.93	78.42	78.48	78.58	78.84
ROU	0.98	1.00	1.00	1.00	1.00	77.55	78.06	78.11	78.20	78.39
RUS	0.97	0.97	0.97	0.97	0.96	77.73	78.12	78.16	78.24	78.45
SVK	1.02	1.00	0.99	0.99	0.98	77.46	77.80	77.84	77.91	78.09
SVN	1.00	0.99	0.99	0.99	0.98	77.50	77.89	77.94	78.02	78.25
SWE	0.98	0.98	0.98	0.98	0.97	70.02	71.31	71.51	71.92	73.24
TUR	1.07	1.07	1.07	1.07	1.05	77.70	78.37	78.44	78.59	78.97
TPKM	1.23	1.20	1.20	1.20	1.18	78.51	78.37	78.36	78.32	78.15
USA	1.22	1.18	1.17	1.16	1.12	77.38	77.90	77.95	78.07	78.45
AVRG	1.08	1.07	1.06	1.06	1.03	76.24	76.83	76.90	77.03	77.42

5.3.4 Uncertainty as Trade Barrier

We convert our estimates of the effects of uncertainty on total trade costs from equation (50) into ad-valorem equivalents as follows:[26]

$$\hat{u^s_{i,t}} = exp(\hat{\gamma}_t tw^s_{ij,t}), \tag{57}$$

where $tw^s_{ij,t}$ is the measure of bilateral uncertainty about tariff changes as described in Section 5.2, and $\hat{\gamma}_t$ is the estimated coefficient on it, reflecting its effect on (log) total trade costs. We visualize the progression of the respective ad-valorem equivalents separately for manufacturing and services trade in Figure 28.[27]

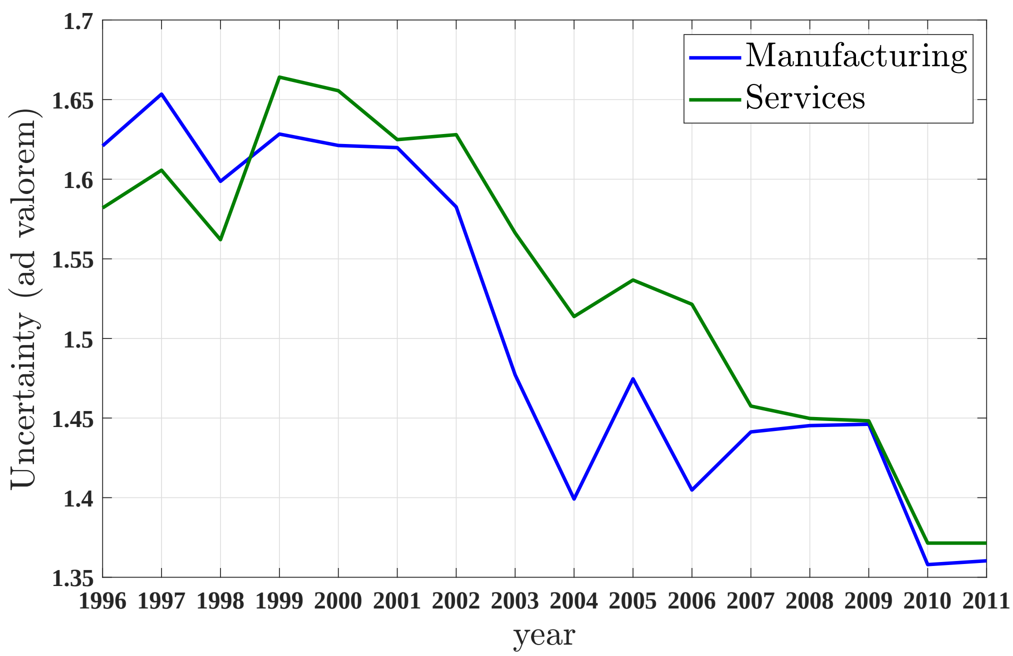


Fig. 28: *Ad-valorem Equivalents of Uncertainty as a Trade Barrier*

The figure suggests that the level of tariff-equivalents of uncertainty as well as its progression over the considered time span is very similar between manufacturing and covered services

[26]One paper that comes to mind when talking about trade-cost uncertainty is the one by Handley and Limão (2017). However, they only address policy uncertainty and not the uncertainty of trade costs in general.

[27]Notice that there is some correspondence between what is classified as services and $tw^s_{ij,t}$ so that tariff-equivalent exist for some (though not all) service sectors.

sectors. Within the sample period the tariff-equivalent of uncertainty peaked in the early years for either type of sectors. The tariff-equivalent of uncertainty has declined quite sharply between the years 2000 and 2005. It declined further, but to a lesser extent, after 2005 until the end of the sample period.

5.4 Total Trade Costs ($TCTC$ and $TPTC$)

This section capitalizes on our theory in combination with the comprehensive and all-inclusive measure of partial equilibrium bilateral trade costs in order to construct and present measures of total trade costs. Since, despite being estimated, the underlying partial equilibrium bilateral trade costs match the data perfectly, the total trade cost indexes that we present in this section can be interpreted interchangeably as total calibrated trade costs ($TCTC$) or as total predicted trade costs ($TPTC$). In addition, as discussed in the theoretical section of this report, $TCTC$ have the advantage of being normalization-free, which means that these indexes can readily be compared across all dimensions of our sample, including countries, sectors and years. To facilitate exposition and to ease interpretation, we first present and discuss the properties of aggregate TCTCs (in Section 5.4.1), then we turn to the analysis of the sectoral TCTCs (in Section 5.4.2).

5.4.1 Aggregated Total Trade Costs

We rely on the aggregation methods that we presented in Section 2.3.1 in order to construct and report aggregate $TCTC$ indexes for each country.[28] Specifically, we obtain and report TCTCs for each exporting country as follows:

$$TCTC_i = \sum_{j \neq i} \frac{E_j}{\sum_{j \neq i} E_j} TCTC_{ij}, \tag{58}$$

[28]The underlying database of sectoral bilateral $TCTC$ indexes for each year in our sample are available by request. Because $TCTC$ cannot be obtained under zero trade flows, we replaced them with the maximum observed value within each country-sector-year observations which is a suitable approximation in such instances.

where the $TCTC_{ij}$ are calculated based on the aggregated trade flows data and the correspondingly calculated outputs and expenditures.

Our main results are reported in Table 10 and presented visually in Figures 29-38. The first four columns of Table 10 present $TCTC$ estimates in levels for 1995, 2000, 2005, and 2011, respectively. The last four columns of Table 10 report percentage changes in $TCTC$ for the periods 1995-1999, 2003-2006, 2009-2011 and 1995-2011, respectively. The focus on these particular periods is motivated below. Figures 29-38 visualize some relationships based on the $TCTC$ numbers in Table 10. Our results suggest the following conclusions with respect to Total Trade Costs:

- *Total Trade Costs are Large.* The average $TCTC$ index across all countries in our sample in 1995, which we report in the bottom of column (1995) of Table 10, is 0.22. We remind the reader that the $TCTC$ bounds are between zero and one, with $TCTC = 1$ indicating frictionless trade. The estimate of 0.22 is significantly below one. While we recognize that a large portion of the difference between our $TCTC$ estimates and frictionless trade can be explained by geographical and other factors that can hardly be affected by trade policy, we also believe that there is significant scope for efficiency improvements and implementation of trade policies that will facilitate international trade. This conclusion is based on the decomposition that described above, which hints at a non-negligible role of tariffs and non-tariff measures. It is also in line with the literature cited and the findings reported in Anderson and van Wincoop (2004, p. 747) that "[t]rade costs are large when broadly defined to include all costs involved in getting a good from producer to final user." The estimates from the bottom row of Table 10 reveal that the total trade costs have moved closer to the frictionless level in 2011, when $TCTC = 0.27$. However, this value is still significantly lower than one. We discuss the evolution of total trade costs over time in more detail below.

- *Total Trade Costs are Very Heterogeneous.* The estimates from columns (1)-(4) reveal

Table 10: *Total Calibrated Trade Costs (TCTC)*

ISO	1995	2000	2005	2011	Δ95-99	Δ03-06	Δ09-11	Δ95-11
AUS	0.144	0.167	0.162	0.190	-1.473	20.232	14.203	23.895
AUT	0.273	0.335	0.343	0.342	13.276	5.790	12.126	19.948
BEL	0.367	0.378	0.375	0.408	-4.113	5.802	8.084	10.000
BGR	0.226	0.310	0.212	0.231	34.259	0.753	2.237	2.266
BRA	0.080	0.092	0.124	0.125	16.011	0.529	14.799	35.577
CAN	0.286	0.301	0.277	0.237	2.508	0.474	1.653	-21.012
CHN	0.071	0.082	0.119	0.098	-4.134	17.931	15.659	28.412
CYP	0.217	0.272	0.235	0.202	11.110	0.634	-0.407	-7.618
CZE	0.224	0.266	0.294	0.324	7.479	12.274	15.420	30.845
DEU	0.185	0.231	0.274	0.296	10.359	15.884	9.351	37.311
DNK	0.238	0.308	0.319	0.334	7.076	13.553	8.873	28.878
ESP	0.107	0.151	0.133	0.168	19.755	2.482	29.117	36.344
EST	0.298	0.361	0.329	0.333	8.273	6.397	1.134	10.550
FIN	0.257	0.286	0.284	0.274	3.553	8.137	10.498	6.311
FRA	0.157	0.183	0.169	0.179	9.113	2.258	14.795	12.637
GBR	0.190	0.193	0.186	0.228	-4.077	4.558	10.390	16.805
GRC	0.068	0.167	0.191	0.194	51.016	22.701	0.257	64.966
HUN	0.217	0.340	0.356	0.419	24.302	17.978	10.520	48.195
IDN	0.177	0.262	0.266	0.213	20.135	8.184	11.475	16.970
IND	0.072	0.096	0.126	0.112	10.940	23.589	14.954	35.581
IRL	0.340	0.477	0.436	0.511	24.430	-4.204	8.682	33.491
ITA	0.138	0.139	0.141	0.164	-7.982	16.394	20.278	15.820
JPN	0.077	0.087	0.111	0.118	2.565	23.372	11.815	34.902
KOR	0.164	0.194	0.204	0.246	12.911	12.204	9.511	33.288
LTU	0.281	0.331	0.403	0.386	0.256	11.591	-1.491	27.313
LUX	0.677	0.648	0.622	0.654	-3.728	-0.862	0.409	-3.479
LVA	0.303	0.280	0.272	0.241	-4.778	-12.355	-0.434	-25.630
MEX	0.207	0.219	0.246	0.271	0.995	16.368	18.271	23.923
MLT	0.507	0.564	0.418	0.410	2.692	-8.747	1.520	-23.754
NLD	0.334	0.347	0.360	0.405	-0.956	10.514	12.317	17.574
POL	0.143	0.173	0.218	0.254	4.404	12.705	14.147	43.618
PRT	0.141	0.164	0.172	0.172	5.993	14.510	2.140	18.157
ROU	0.139	0.204	0.227	0.202	14.299	7.594	-0.289	30.918
RUS	0.214	0.325	0.272	0.243	33.398	0.374	12.510	12.008
RoW	0.203	0.275	0.342	0.255	6.705	16.968	0.374	20.457
SVK	0.279	0.302	0.372	0.328	-3.326	18.033	2.320	14.997
SVN	0.253	0.281	0.330	0.304	-0.656	15.541	4.647	16.687
SWE	0.260	0.294	0.304	0.309	4.973	10.008	0.571	15.679
TUR	0.082	0.092	0.100	0.139	12.162	17.121	8.695	41.456
TPKM	0.244	0.305	0.374	0.423	12.964	13.693	10.135	42.328
USA	0.111	0.112	0.107	0.132	-2.829	10.917	14.630	15.404
AVRG	0.218	0.258	0.263	0.270	8.414	8.555	7.702	19.174

that $TCTC$ vary widely, but also intuitively, across countries. Thus, for example, the countries that consistently appear to be the closest to frictionless trade include Luxembourg, Malta, Belgium, Ireland, and the Netherlands. Favorable geographical location as well as strong and intensive integration with other (often larger) economies from the European Union are natural candidates to explain this result. On the other side of the spectrum, we find countries that are far away from frictionless trade. Prominent examples include Chine, India, Japan and Brazil. Geographical isolation probably drives these results. This intuition is supported by the fact that the United States also has relatively low $TCTC$. Another country that has low total trade costs is Turkey. Despite Turkey's good geographical location, a possible explanation for the large total trade costs for this country is that it is not part of the European Union. Finally, our estimates reveal that Greece is also a country with very large total trade costs. This result may seem a bit puzzling, since Greece has geographical location and characteristics that should favor trade (e.g. Greece, is close to some of its most important and large trading partners, and it has direct access to seas). In addition, Greece is a member of the European Union, as such this country has preferential access to some of the largest markets in the world, e.g. Germany and France. A possible explanation for Greece's large trade costs could be that this country had an enormous government sector during the period of investigation. Furthermore, Greece is one of the countries that experienced the largest asymmetries between $TCTC$ on the exporter side vs. $TCTC$ on the importer side, with significantly larger $TCTC$ on the exporter side, which is what we report and discuss so far. Next, we discuss such asymmetries in more detail.

- *$TCTC$ are Relatively Symmetric on the Exporter vs. the Importer Side.* With some exceptions, total trade costs are relatively symmetric on the exporter and on the importer side for each country, with most countries facing relatively higher trade costs on the exporter side (lower $TCTC$). These relationships are revealed in Figures 29-32, where we plot $TCTC$ that are aggregated on the exporter side vs. $TCTC$ that are aggregated for each country as an importer as follows:

$$TCTC_j = \sum_{i \neq j} \frac{Y_i}{\sum_{i \neq j} Y_i} TCTC_{ij}. \tag{59}$$

Figures 29-32 plot the relationship between exporter and importer $TCTC$ for 1995, 2000, 2005, and 2011, respectively. Three main findings stand out from these figures.

First, we see that most countries are clustered close around the 45-degree line. This suggests that the trade costs that countries face as exporters and as importers are relatively symmetric. Second, we note that Australia and Russia are the two countries that appear consistently above the 45-degree line on each figure, i.e. in each year. This means that these two economies, and especially Russia, face significantly larger trade costs as importers. A possible explanation for Russia's case is that a significant fraction of this country's exports are in resource industries with well-established transportation channels, e.g. natural gas. Finally, we also see several countries that appear consistently below the 45-degree line, which means that they face larger trade costs as exporters. Some examples include Cyprus, Greece, Hungary, Romania. A possible explanation for these findings is that these economies are less developed and much more dependent on imports.

- *Total Trade Costs Have Become More Symmetric Over Time.* This can be seen by comparing the distributions of $TCTC$ in Figures 29-32. While one can still see that Cyprus and Greece appear to the furthest right from the 45-degree line in Figure 32, which presents our estimates for the last year in the sample (2011), comparison between Figures 29 and 32 reveals that countries are clearly more clustered around the 45-degree line in 2011. This result is even more pronounced if we compare Figures 30 and 32.

- *Total Trade Costs Have Fallen Over Time on Average.* Figure 33 and Figure 34 plot

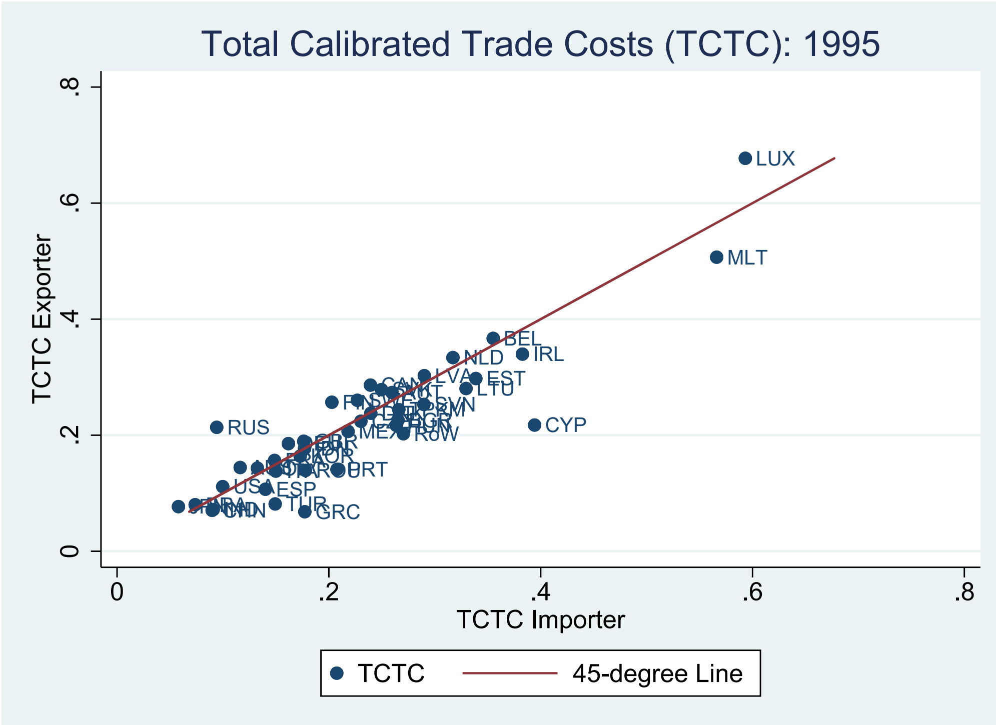


Fig. 29: *Total Calibrated Trade Costs, 1995*

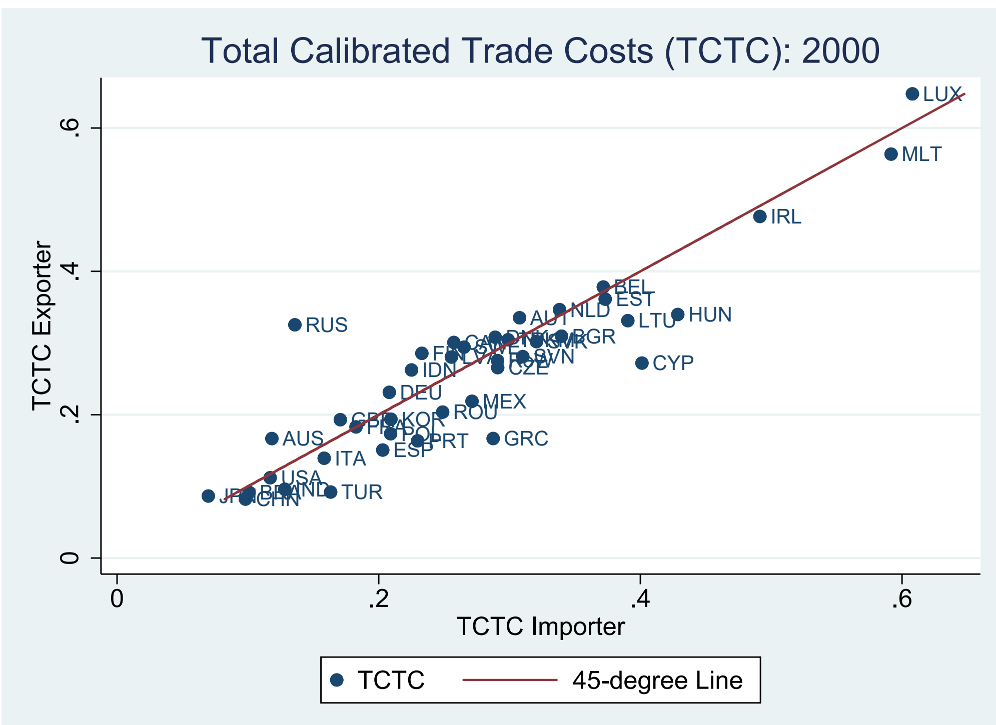


Fig. 30: *Total Calibrated Trade Costs, 2000*

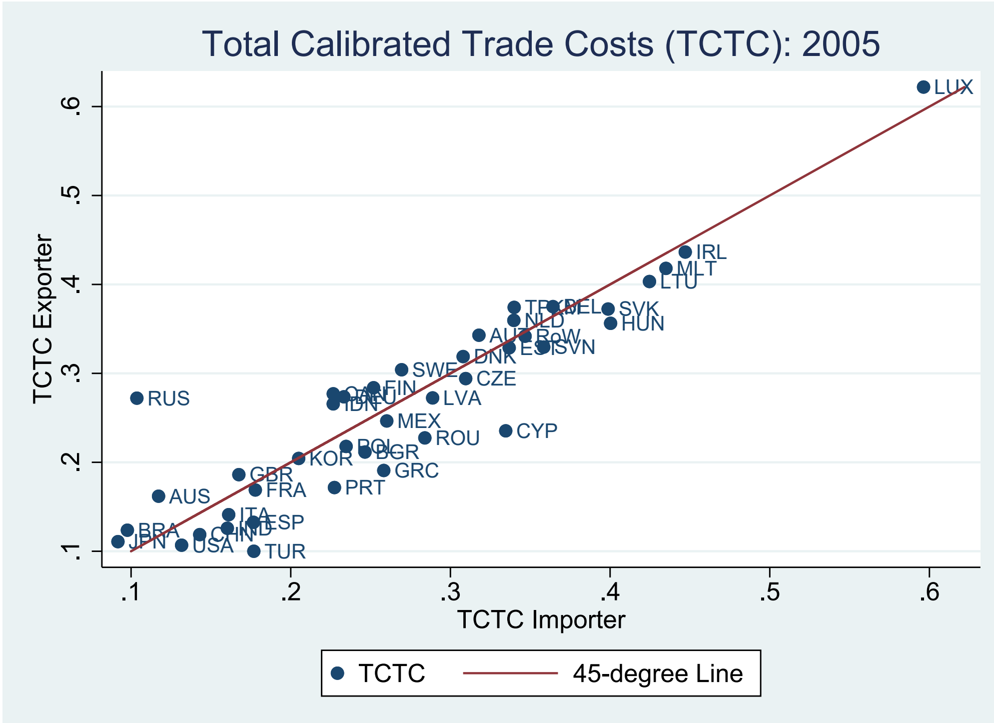


Fig. 31: *Total Calibrated Trade Costs, 2005*

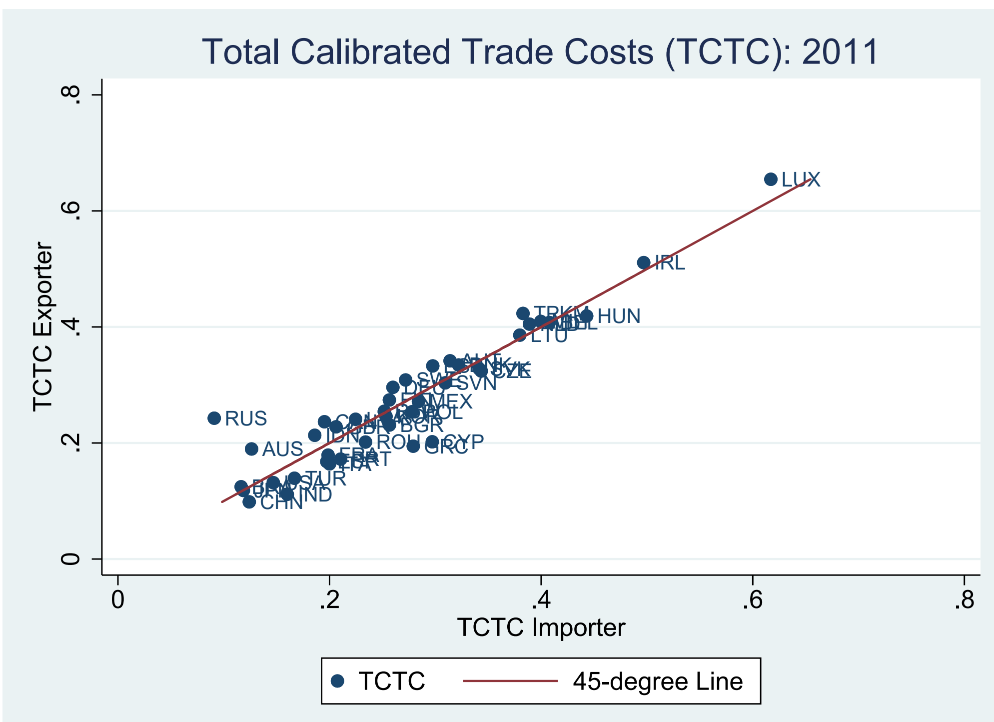


Fig. 32: *Total Calibrated Trade Costs, 2011*

the evolution of average total trade costs over the period of our sample coverage, 1995-2011. Figure 33 plots the evolution of a simple average and export-weighted average of the $TCTC$ indexes across all countries, which are constructed according to equation (58), while Figure 34 reports the evolution over time of the simple average of a transformed total trade cost index $TCTC^{-1/\theta}$, where we use $\theta = 6$, which is standard in the literature (see Anderson and van Wincoop, 2003; Head and Mayer, 2014). The advantages of reporting the transformed $TCTC$ index are that (i) it allows for direct interpretation of the evolution of total trade costs, i.e. a negative slope implies decreasing trade costs; and (ii) it offers a measure that can be interpreted in the spirit of the famous iceberg cost from the trade literature. As can be seen from Figure 34, our transformed $TCTC$ vary between 1.4 and 1.6, which is plausible and within the theoretical bounds from one to infinity.

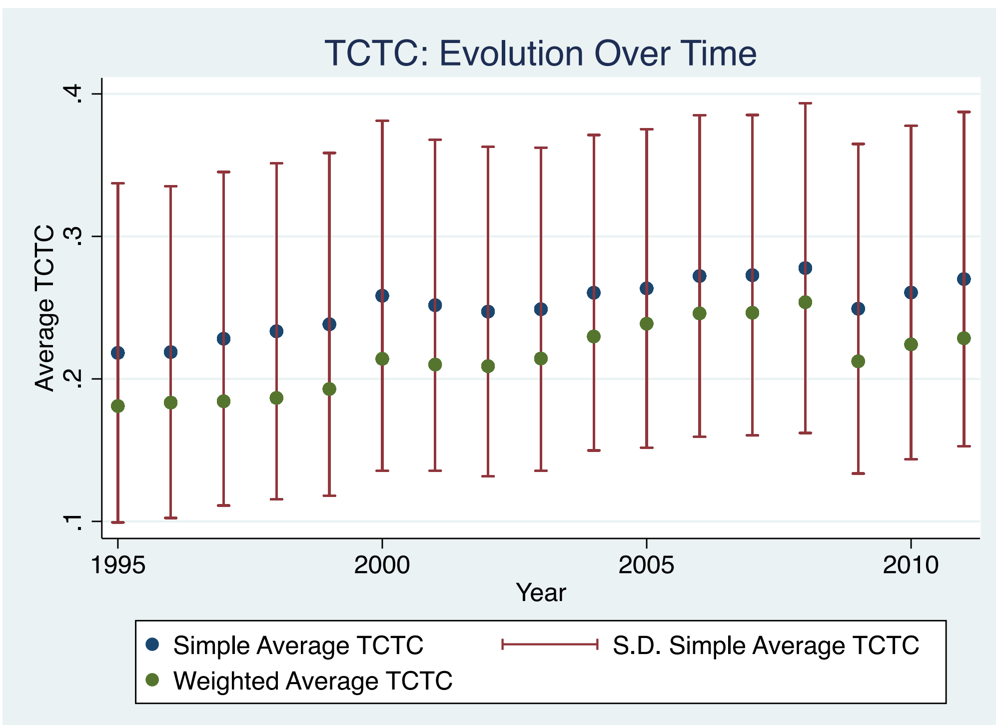


Fig. 33: *Average TCTC: Evolution Over Time, 1995-2011*

The main finding from Figures 33 and 34 is that the average total trade costs in our

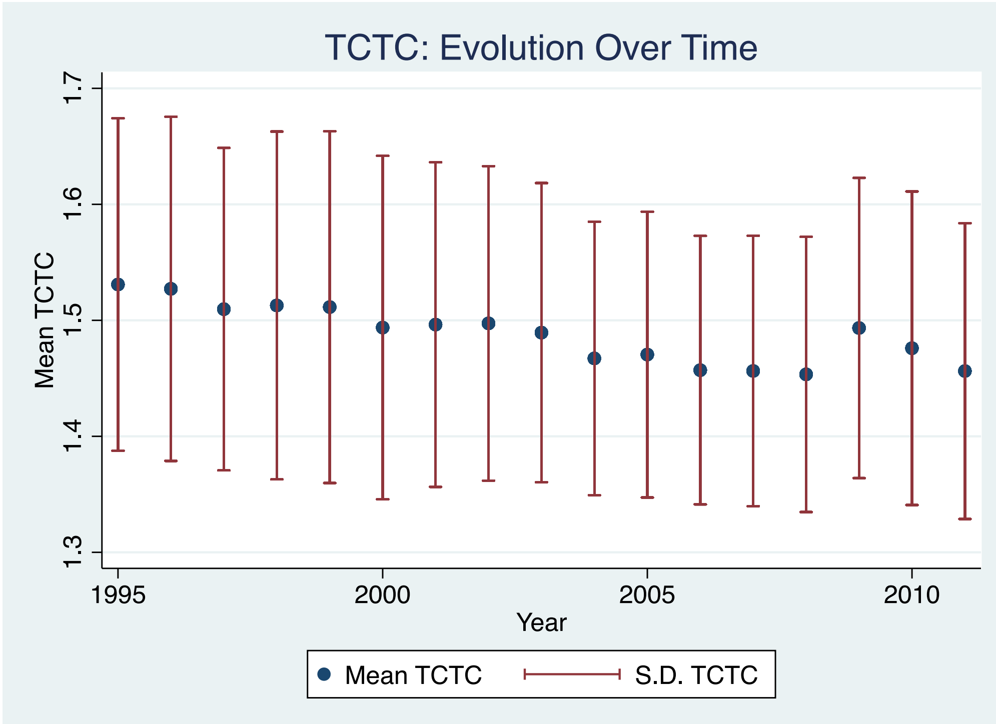


Fig. 34: *Average* $(TCTC)^{-1/\theta}$*: Evolution Over Time, 1995-2011*

sample have fallen over time.[29] The bottom row in column ($\Delta 95 - 11$) from Table 10 reveals that the percentage change in $TCTC$ over the period 1995-2011 is about 19.2 percent. The total change in $TCTC$ over the period of investigation is significant but it may seem moderate to some, especially given all the intensive integration efforts during the 1990s and early 2000s. We offer two possible explanations for this result. First, the period of investigation in our study covers two global recessions (in 2001 and 2008). Second, the last year of our sample is 2011, a year that is too close to the Great Recession. We elaborate on these observations next.

- *The Change in* $TCTC$ *is Non-monotonic.* The second main finding from Figures 33 and 34 is that trade costs increase around 2001-2002 and around 2007-2009. As noted above, our explanation for these spikes in total trade costs are the two global recessions of 2001 and 2008. Motivated by this observation, in columns (5), (6) and (7) of Table 10

[29] We also note that the average and export-weighted average trade costs and, especially, their evolution over time are not very different from each other. As we will see later, this will change when we present and discuss the sectoral TCTCs.

and in Figures 35 to 37 we describe the evolution of $TCTC$ in three separate periods, namely 1995-1999, 2003-2006, and 2009-2011. Figure 38 reports the corresponding change over the whole period of investigation.

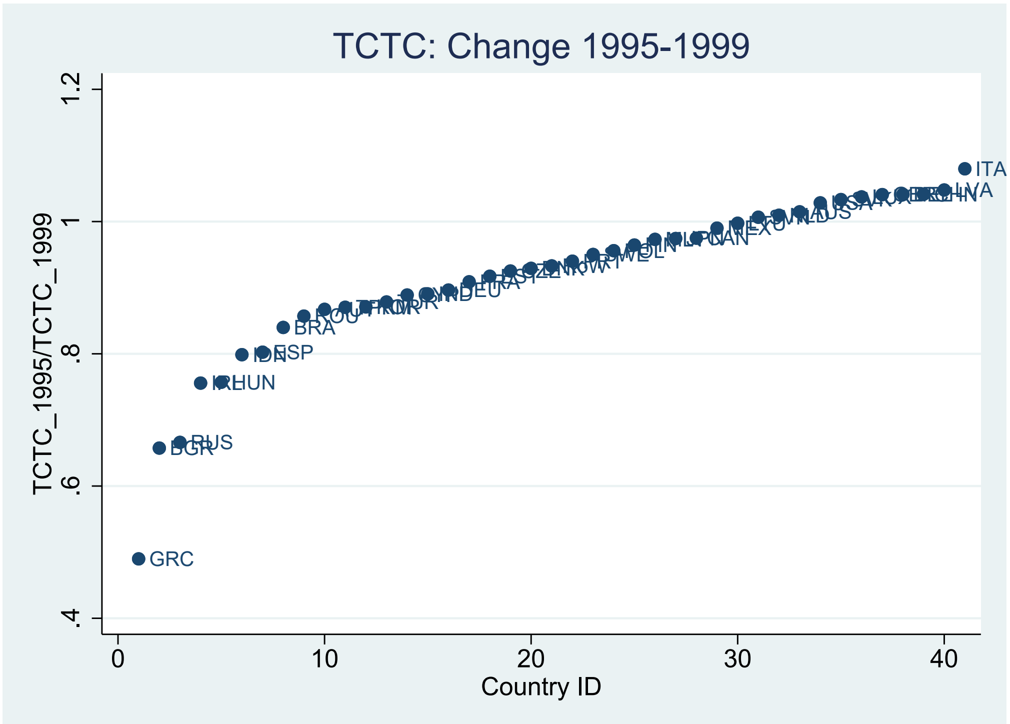


Fig. 35: Δ *Total Calibrated Trade Costs, 1995-1999*

The results from the table and from the figures capture several intuitive relationships. First, we see that the decrease in total trade costs during the period 1995-1999 is about 8.1 percent. The intensive trade liberalization efforts, e.g. in the form of many bilateral and multilateral free trade agreements, during this period of investigation offer a natural explanation for this result. The percentage change in total trade costs between 2003 and 2006 is about 8.6 percent. Finally, we obtain a 7.1 percent decrease in total trade costs during the period 1999-2011. This change is comparable to the change during the period 2003-2006. However, the explanation here is that this change reflects a bounce back from the sharp and deep fall in trade costs during the Great Recession.

- *The Change in* $TCTC$ *Over Time is Heterogeneous Across Countries.* Finally, we note

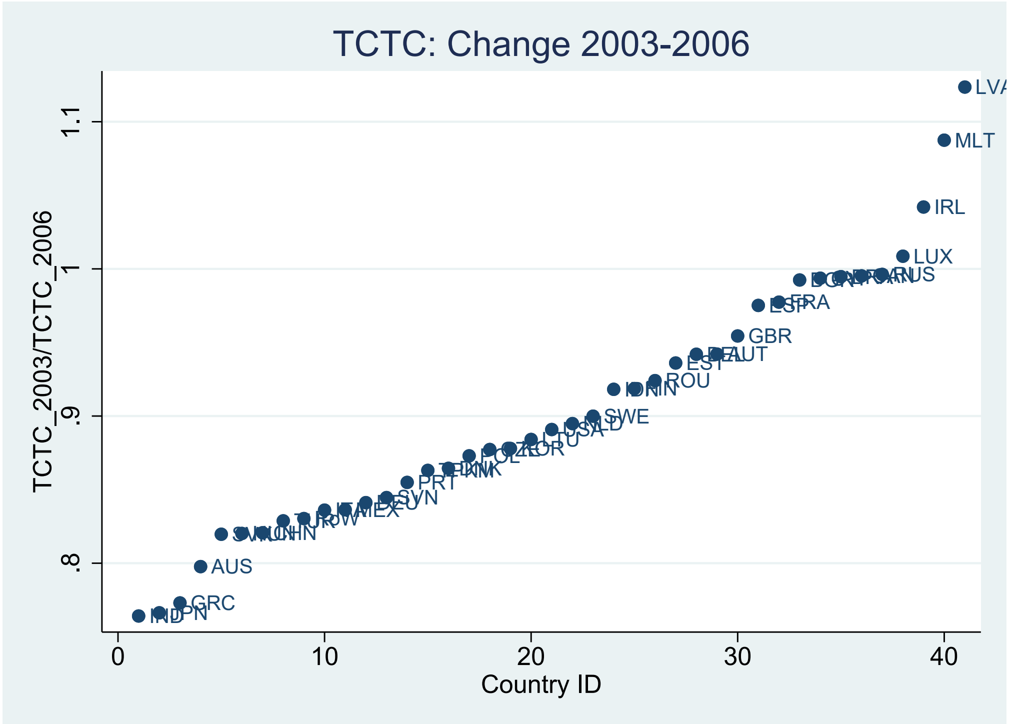


Fig. 36: Δ *Total Calibrated Trade Costs, 2003-2006*

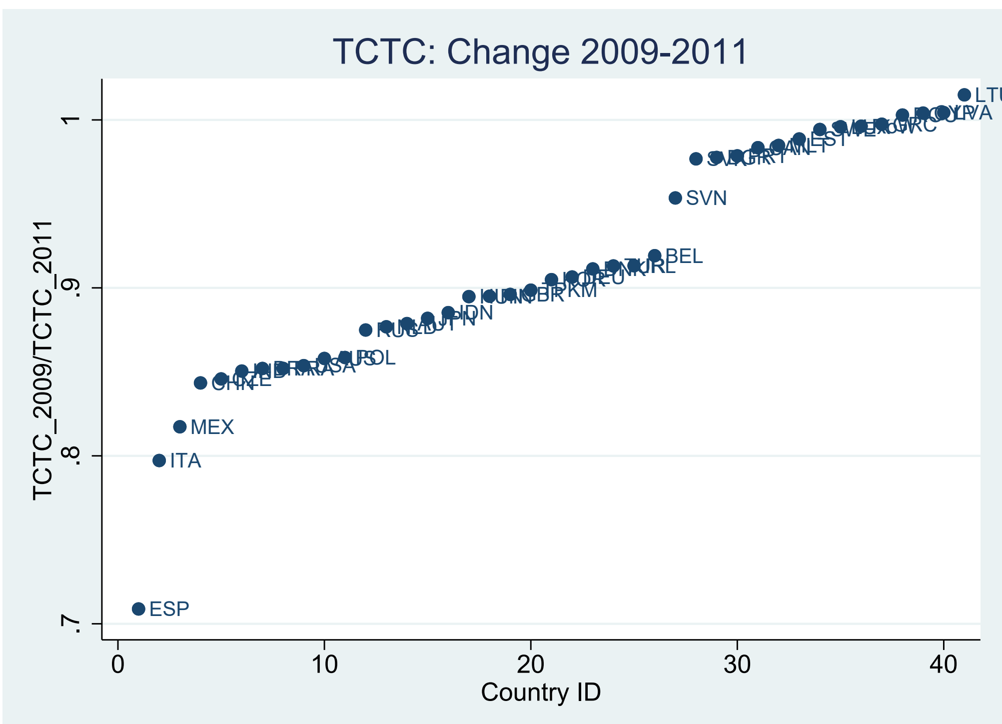


Fig. 37: Δ *Total Calibrated Trade Costs, 2009-2011*

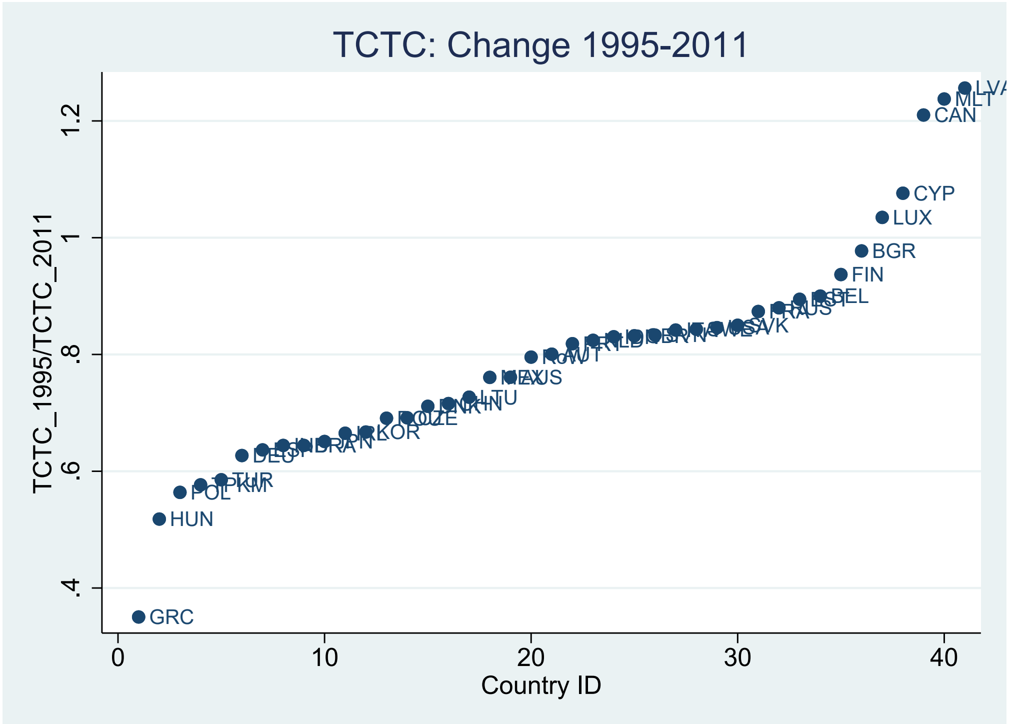


Fig. 38: Δ *Total Calibrated Trade Costs, 1995-2011*

that the change in total trade costs over the period 1995-2011 has been very heterogeneous across countries but also within the subsamples of periods. Overall, the countries that enjoyed the largest decrease in total trade costs between 1995 and 2011 include Greece, Hungary and Poland. Integration with the European Union is a natural explanation for this result. On the other side of the spectrum, we find countries such as Malta, Cyprus, Luxembourg and Canada, which suffered an increase in trade costs during the period 1995-2011. In the case of Latvia, this country experienced increasing trade costs during each of the three subsample periods, which were magnified and reinforced by further decreases during the recessions. A possible explanation for this result is Latvia's slow recovery after the collapse of communism. In the case of Luxembourg, the overall increase in trade costs is only small and it reflects a combination of falls and increases in trade costs during the subsamples. Finally, total trade costs in Canada have fallen moderately in each of the three subsamples, but this country experiences an overall increase in trade costs. Therefore, the explanation for the overall increase in trade costs in Canada is that this country has been hit hard by the recessions.

5.4.2 Sectoral Total Trade Costs

This section presents and discusses TCTC estimates at the sectoral level. In order to keep exposition manageable and to focus on some of the most important properties of the sectoral TCTCs, we rely on the aggregation methods that we presented in Section 2.3.1 in order to construct and report $TCTC$ indexes for each sector and for each year in our sample. The underlying database of sectoral bilateral $TCTC$ indexes for each year and country in our sample are available by request.

- *Total Trade Costs: Main Sectors.* We start our analysis with a discussion of TCTCs across the four main categories in our sample, which include Agriculture, Mining, Manufacturing, and Services. Figures 39 and 40 present the evolution of the simple average TCTCs and export-weighted average TCTC estimates, respectively, over the sample period 1995-2011. We remind the reader that, by construction, the TCTCs are free of any normalization. Therefore, we can offer valid comparisons across any of the dimensions of our data. In particular, in this section we will focus on comparisons over time and across sectors.

  Before we discuss the TCTC estimates, we note that, unlike the case of the aggregate trade costs that we discussed in the previous section, the simple average TCTCs and the export-weighted TCTCs could be quite different. Specifically, comparison of the results from Figures 39 and 40 reveals the following: (i) Weighting does not play a very significant role in the case of Agriculture and Manufacturing; and (ii) The export-weighted TCTCs for Mining and for Services are considerably larger as compared to the corresponding simple-average indexes. Mechanically, the explanation for this result is that some major exporters in Mining and Services face significantly lower costs as compared to smaller exporters. Given the pronounced differences between Figures 39 and 40, we will focus our analysis on export-weighted averages for the rest of this

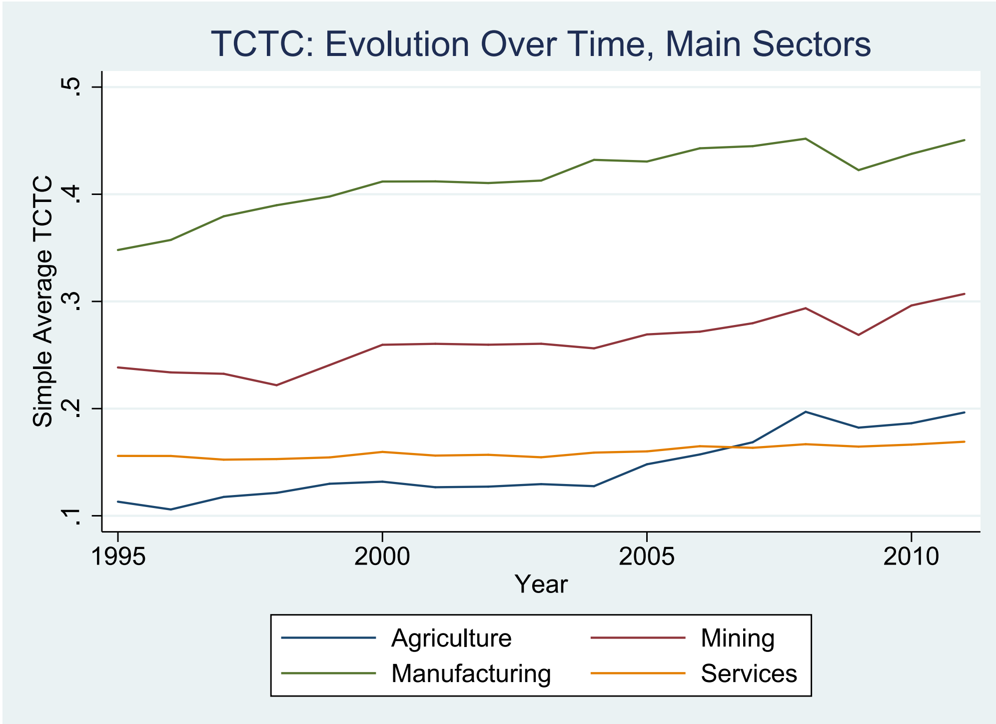


Fig. 39: *Simple Average TCTC: Evolution Over Time. Main Sectors.*

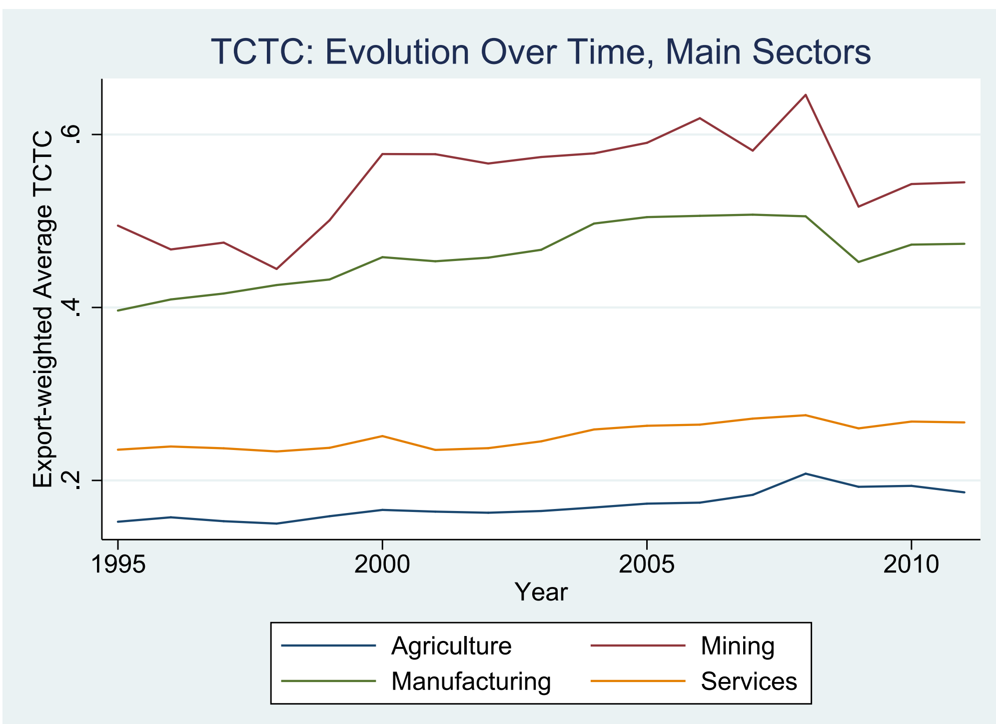


Fig. 40: *Weighted Average TCTC: Evolution Over Time. Main Sectors*

section. The estimates from Figure 40 suggest the following:

- *TCTC Levels.* In terms of levels, TCTCs in Agriculture and in Services are discretely and significantly lower (trade costs are higher) as compared to the TCTCs in Mining and Manufacturing. A possible explanation in the case of Agriculture is that this is the category that is probably subject to most intense regulation and policy influence. Another explanation in the case of Agriculture could be the significant transportation costs for trade of agricultural products. The natural main explanation for the lower TCTCs in the case of Services is their highly localized consumption (and production). We also suspect that policy obstacles in the case of services must play a significant role for the large TCTCs. Specialization and well-established trade relationships are possible candidates to explain the relatively low total trade costs in the case of manufacturing. Finally, we attribute the relatively high TCTCs in the case of Mining to specialization, long-standing relationships and, in some cases, low variable costs of delivery, e.g. pipes.

- *TCTC Evolution Over Time.* Turning to the evolution of TCTCs over time, we note the following. First, without any exception, all main categories have enjoyed an increase in TCTCs. Second, the changes are heterogeneous across the four categories. According to our estimates, on average, Agriculture and Manufacturing experience changes of about 20 percent, while Services and Mining TCTCs changed by about 10 percent. Third, TCTCs in Mining are most volatile. Fourth, all categories suffered increase in trade frictions during the Great Recession. Fifth, the impact of the Great Recession was most pronounced in Mining and Manufacturing. Sixth, Mining is the sector that has recovered the least after the Great Recession. Finally, we note that the trend of decreasing TCTCs (increasing trade costs in Agriculture is still ongoing in 2011.

- *Total Trade Costs in Manufacturing.* Next, we turn to the analysis of the levels and evolution of total trade costs in Manufacturing. While there is significant variation in the levels of manufacturing trade costs, overall they move together across the different Manufacturing sectors. Therefore, we chose to present all manufacturing sectors together in Figure 41. In addition, Table 11 offers a series of sectoral TCTC indexes including sectoral averages over the period of investigation (column (1)), TCTC levels for each sector in 1995, 2003, and 2011 (in columns 2-4, respectively), and the percentage change in TCTC over the period 1995-2011 (in column (5)). The indexes from Table 11 and Figure 41 reveal the following:

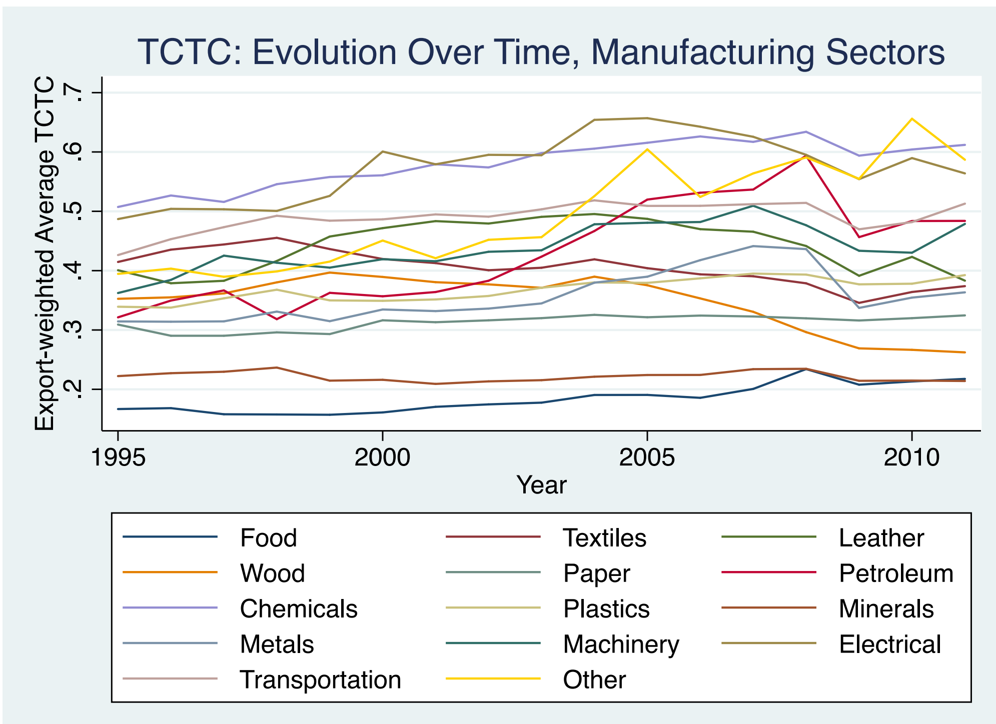


Fig. 41: *Weighted Average TCTC: Evolution Over Time. Manufacturing Sectors*

  - *Manufacturing TCTCs: Levels.* TCTCs in manufacturing vary significantly (but mostly intuitively) across sectors. With values of less than one-third of their hypothetical frictionless trade potential, "Food, Beverages and Tobacco," "Non-Metallic Mineral Products," and "Pulp, Paper, Printing and Publishing," are the sectors that face the largest trade costs (lowest TCTCs). On the other side of the

Table 11: *Total Calibrated Trade Costs per Sector, 1995-2011*

	Total Trade Costs per Sector				
Sector Description	Mean	1995	2003	2011	%Δ95/11
Agriculture, Hunting, Forestry and Fishing	0.17	0.15	0.16	0.19	22.31
Mining and Quarrying	0.55	0.49	0.57	0.54	10.13
Food, Beverages and Tobacco	0.18	0.17	0.18	0.22	30.50
Textiles and Textile Products	0.41	0.41	0.40	0.37	-9.82
Leather, Leather Products and Footwear	0.44	0.40	0.49	0.38	-4.39
Wood and Products of Wood and Cork	0.35	0.35	0.37	0.26	-25.60
Pulp, Paper, Printing and Publishing	0.31	0.31	0.32	0.32	5.01
Coke, Refined Petroleum and Nuclear Fuel	0.43	0.32	0.42	0.48	50.60
Chemicals and Chemical Products	0.58	0.51	0.60	0.61	20.62
Rubber and Plastics	0.37	0.34	0.37	0.39	15.72
Other Non-Metallic Mineral	0.22	0.22	0.22	0.21	-3.69
Basic Metals and Fabricated Metal	0.36	0.31	0.34	0.36	15.60
Machinery, Nec	0.44	0.36	0.43	0.48	32.15
Electrical and Optical Equipment	0.57	0.49	0.59	0.56	15.80
Transport Equipment	0.49	0.43	0.50	0.51	20.32
Manufacturing, Nec; Recycling	0.49	0.39	0.46	0.59	48.75
Electricity, Gas and Water Supply	0.10	0.06	0.11	0.12	106.85
Construction	0.06	0.05	0.06	0.07	24.37
Sale, Maintenance and Repair of Vehicles	0.09	0.07	0.08	0.11	62.79
Wholesale Trade and Commission Trade	0.20	0.18	0.19	0.22	25.19
Retail Trade, Except of Motor Vehicles;	0.11	0.13	0.10	0.10	-22.10
Hotels and Restaurants	0.32	0.25	0.32	0.34	39.62
Inland Transport	0.24	0.20	0.24	0.27	36.46
Water Transport	0.73	0.72	0.73	0.70	-2.13
Air Transport	0.57	0.57	0.55	0.63	10.32
Other Supporting and Auxiliary Transport	0.24	0.27	0.22	0.24	-11.84
Post and Telecommunications	0.09	0.09	0.08	0.10	20.28
Financial Intermediation	0.22	0.15	0.19	0.30	96.78
Real Estate Activities	0.08	0.05	0.07	0.13	145.59
Renting of MandEq and Other Business	0.18	0.15	0.19	0.18	19.12
Public Admin and Defence	0.12	0.10	0.10	0.16	58.40
Education	0.21	0.30	0.21	0.21	-31.39
Health and Social Work	0.10	0.15	0.08	0.09	-40.52
Other Community, Social and Personal	0.11	0.10	0.11	0.10	-7.70
Private Households with Employed Persons	0.12	0.07	0.19	0.05	-20.59

spectrum, with TCTC values of close to 0.6, we find “Chemicals and Chemical Products” and “Electrical and Optical Equipment,” closely followed by “Transport Equipment” with TCTC above 0.49. Overall, we find the variation of TCTCs across sectors to be intuitive. An important task for researchers and policy makers is to identify what components of TCTCs, and to what degree, are subject to possible policy influence.

– *Manufacturing TCTCs: Evolution Over Time.* Several main results stand out from an analysis of the evolution of Manufacturing TCTCs over time. First, the estimates from Table 11 and Figure 41 reveal that some sectors have enjoyed a significant movement toward frictionless trade. These sectors include “Food, Beverages and Tobacco,” “Machinery” and “Coke, Refined Petroleum and Nuclear Fuel”. While, at least some part of the large percentage change in “Food, Beverages and Tobacco” can be attributed to the fact that this is the sector with the lowest initial base, the large changes in “Machinery” and “Coke, Refined Petroleum and Nuclear Fuel” must have been driven by significant policy and/or other globalization forces.

  Second, we see a few industries, including “Non-Metallic Minerals,” “Leather, Leather Products and Footwear,” “Textiles and Textile Products,” and “Wood and Products of Wood and Cork,” where the total trade costs have actually increased between 1995 and 2011. With a percentage change of -25.6 percent, the decrease in TCTCs is the largest in “Wood and Products of Wood and Cork”.

  Third, we find that all sectoral TCTC indexes reflect the influence of the great Depression. Naturally, on average, the increases in trade frictions during the Great Recessions are larger for the more open sectors.

  Fourth, we see that by 2011 TCTCs in most sectors (except for “Pulp, Paper, Printing and Publishing” and “Machinery”) have not recovered to their 2008 values. The difference, of more then -15 percent (between 2008 and 2011) is most pronounced in “Coke, Refined Petroleum and Nuclear Fuel” and “Basic Metals and Fabricated Metal”.

- *Total Trade Costs in Services.* Similar to the analysis of the Manufacturing TCTCs, we analyze the levels and the evolution over time of the total trade costs for the services sectors in our sample. To aid presentation, for each sector we report means over the period of investigation, levels for 1995, 2003, and 2011, and percentage changes over the period of investigation (1995-2011) in Table 11. In addition, we offer a visualization of the TCTCs for each services sectors in a series of figures, which we describe below.

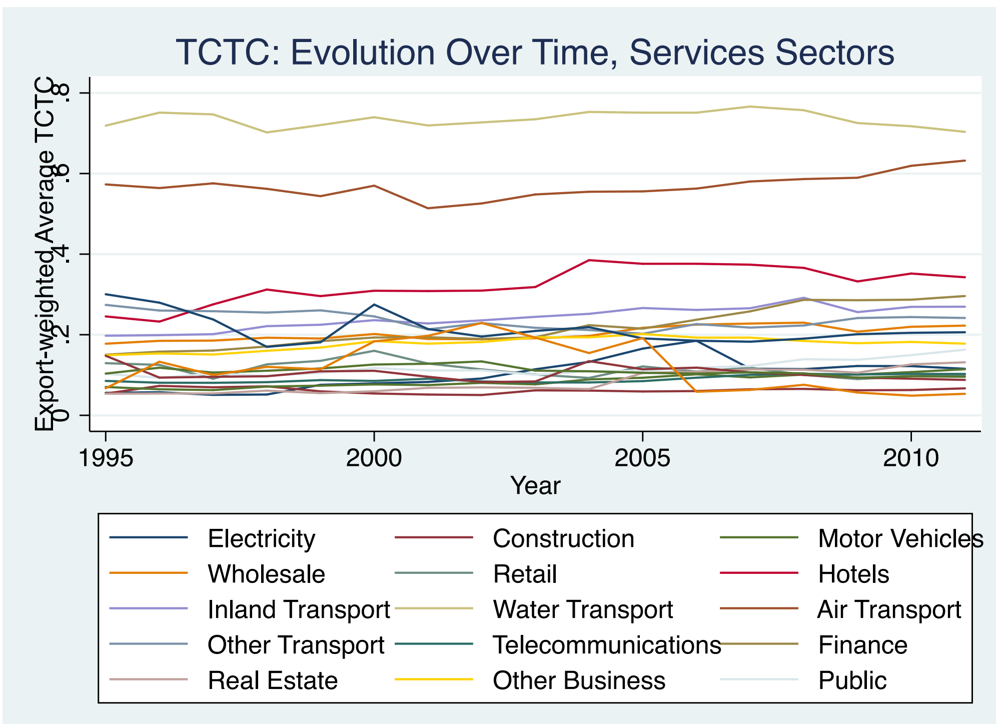


Fig. 42: *Weighted Average TCTC: Evolution Over Time. Services Sectors*

  – *Services TCTCs: Levels.* Figure 42 presents the evolution of TCTCs for each services sector in our sample. The main messages from this figure with regard to the level of total trade costs in services is that they are substantial, on average, and that they vary significantly across sectors. Unlike manufacturing, where we observed a more clear and consistent picture across sectors, the TCTC plot for the services sectors is not so clear. Therefore, we present them in several figures.

Figure 43 plots the evolution of the services TCTCs for the sectors with the lowest trade costs, those with average TCTC indexes above 0.3. Not surprisingly, these sectors include "Water Transport," "Air Transport," and "Hotels and Restaurants," of which (with an average value of 0.73) "Water Transport" is the sector with the highest TCTCs not only across all services sectors but also across all sectors in the sample. The higher level of overall trade costs in services as compared to manufacturing is consistent with the findings in Egger, Larch and Staub (2012) and Anderson et al. (2015).

"Inland Transport" and "Other Supporting and Auxiliary Transport Activities and Agencies" are two other categories with relatively low total trade costs but, for expositional clarity, we decided to put them in the second group of sectors with medium TCTCs, which also includes "Intermediation," "Education," "Wholesale Trade and Commission Trade, Except of Motor Vehicles," and "Renting of M&Eq and Other Business Activities". The sectors with medium trade costs are included in Figure 44.

Finally, Figures 45 and 46 include the services sectors with the highest trade costs (lowest TCTCs). As expected, here we find categories such as "Construction," which is the sector with the lowest TCTCs in our sample, "Real Estate Activities," "Electricity, Gas and Water Supply," "Health and Social Work," and "Other Community, Social and Personal Services". Highly localized consumption is the natural explanation for the large trade costs in these sectors. We split the sectors with the largest trade costs in two groups based on their evolution over time, which is the object of the next discussion.

– *Services TCTCs: Evolution Over Time.* Several main results stand out from the

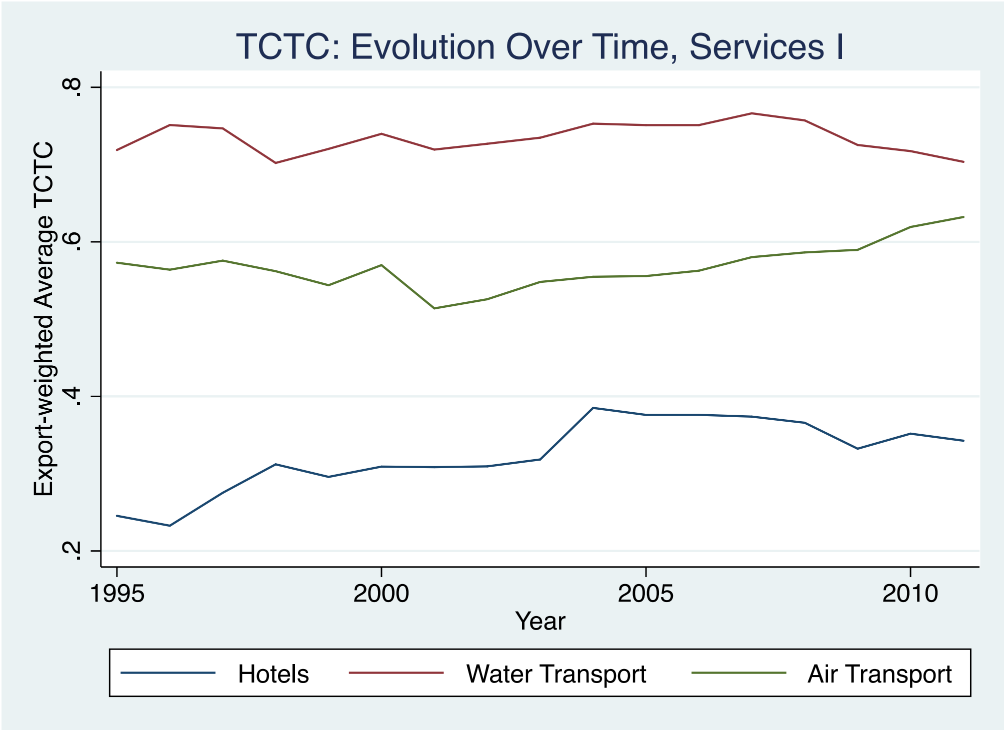


Fig. 43: *Weighted Average TCTC: Evolution Over Time. Low-cost Services*

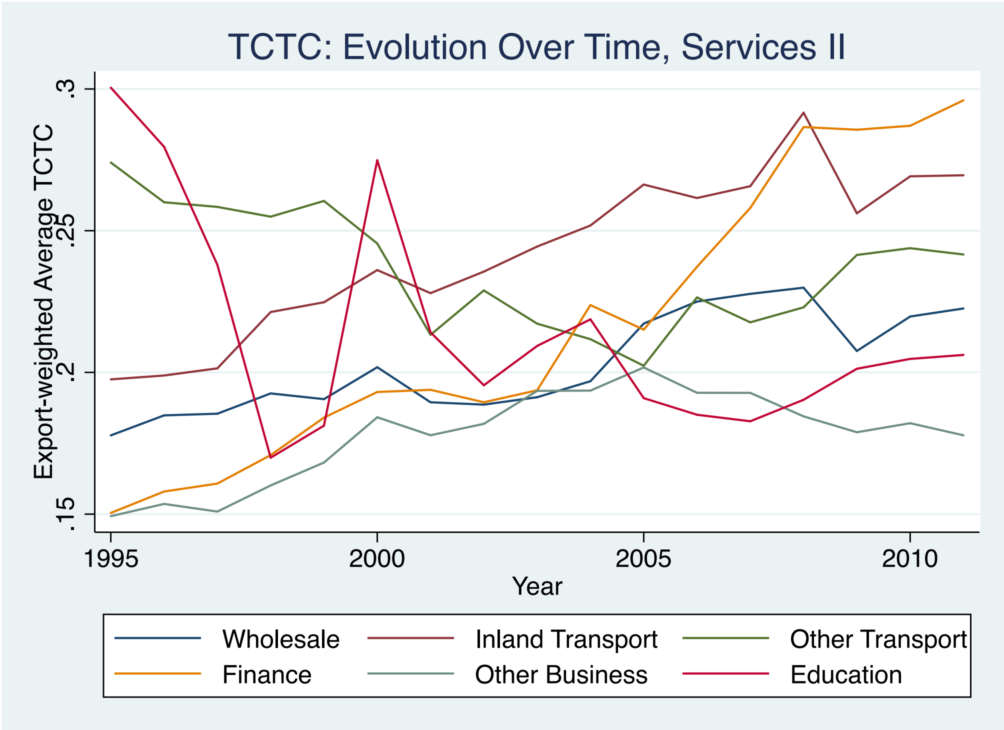


Fig. 44: *Weighted Average TCTC: Evolution Over Time. Medium-cost Services*

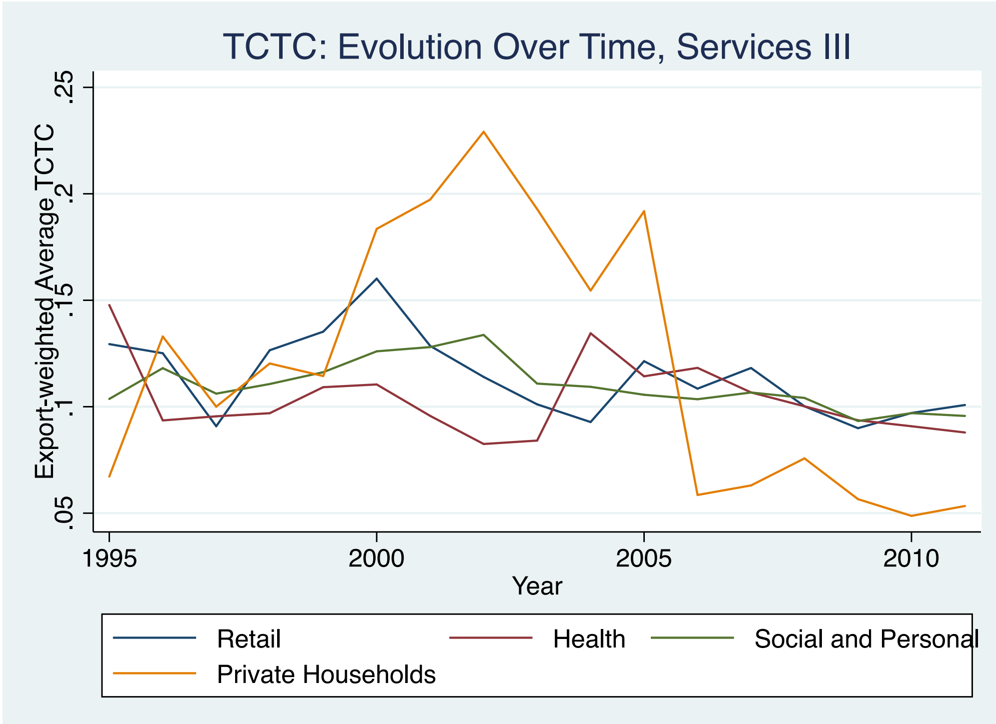


Fig. 45: *Weighted Average TCTC: Evolution Over Time. High-cost Services I*

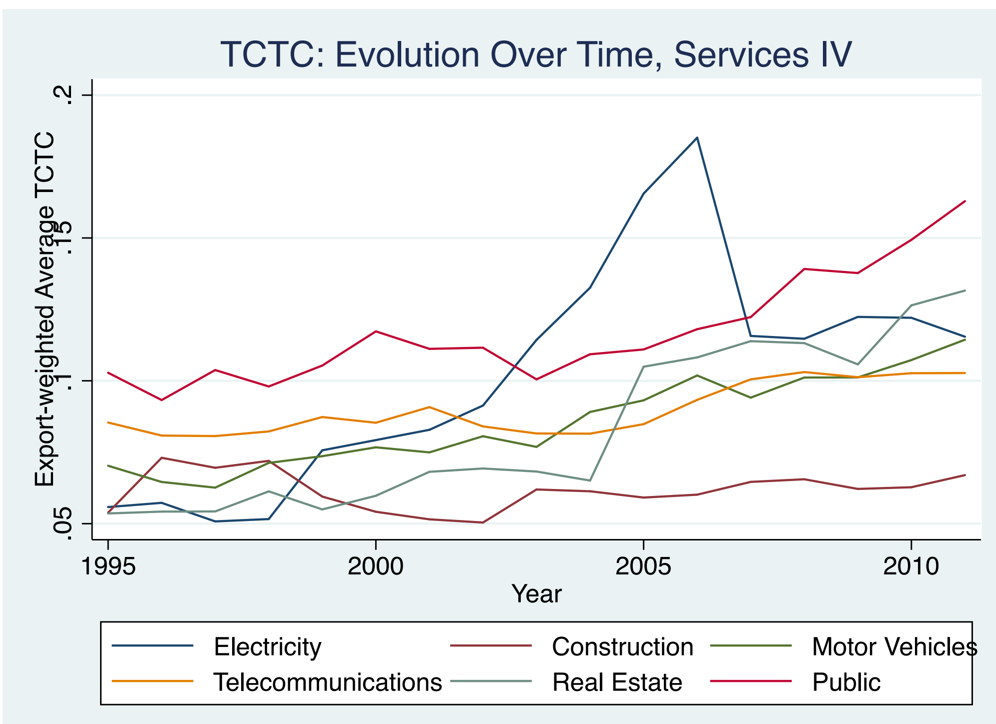


Fig. 46: *Weighted Average TCTC: Evolution Over Time. High-cost Services II*

analysis of the evolution of the services TCTCs over time. First, TCTCs in five sectors have changed by more than 50 percent toward frictionless trade. These sectors include "Real Estate Activities," "Electricity, Gas and Water Supply," "Financial Intermediation," "Sale, Maintenance and Repair of Motor Vehicles and Fuel," and "Public Admin and Defence; Compulsory Social Security". The natural explanation for the large percentage decrease of trade costs in four of these categories (except "Financial Intermediation") is that they are among the sectors with the smallest TCTC values (corresponding to largest total trade costs). This is why we have grouped these industries, along with some of the other high-cost services sectors in Figure 46. We find it interesting and important that trade costs in sectors with such pronounced localized services consumption do experience decreases in trade costs. "Financial Intermediation" is the only sector with relatively high TCTCs, which experienced a change of more than 50 percent. While, in principle, the large fall in total trade frictions in the "Financial Intermediation" sector should be viewed as efficiency improving, we note that the largest increase in TCTCs in Financial Services occurred before 2007, which, in turn, may have facilitated the spread of the Great Recession in the world economy.

Second, seven services sectors in our sample experienced an increase in trade costs. Four of these categories are sectors that are among those with the lowest TCTCs, including "Health and Social Work," "Retail Trade, Except of Motor Vehicles; Repair of Household Goods," "Private Households with Employed Persons," and "Other Community, Social and Personal Services". In addition, in this group we also find "Education," "Water Transport," and "Other Transport Activities," which are among the sectors with relatively high TCTCs. Finally, we note that the impact of the Great Recession on TCTCs is not so pronounced among the services sectors, and for many of them we do not see a sharp impact during the period 2008-2009. "Wholesale Trade and Commission Trade, Except of Motor

Vehicles" and "Inland Transportation" are two exceptions.

5.5 General Equilibrium Trade Costs ($GETC$)

This section capitalizes on our theory in combination with the comprehensive and all-inclusive measure of partial equilibrium bilateral trade costs in order to construct and present measures of the general equilibrium trade costs ($GETC$). Using the structural decomposition that we describe in Section 2.2.2, we constructs GETCs for each pair of countries, sector and year in our sample. In order to keep the analysis manageable, we aggregate the GETC indexes across countries to the sectoral level and we report the evolution of the sectoral indexes over time. The GETC estimates across all sectors in our sample are reported in Table 12. Column (1) reports average indexes over the period of investigation. Columns (2), (3), and (4) report GETCs for the first, middle, and last year, and the last column reports percentage changes in GETCs over the whole period of investigation. In addition, Figures 47-50 report GETCs for the four main sectors, including Agriculture (in Figure 47), Mining (in Figure 48), Manufacturing (in Figure 49), and Services (in Figure 50). In addition to the GETC indexes Figures 47-50 also include the graphs of the corresponding TCTCs.

Three main findings stand out based on the GETC indexes that we report in Table 12 and Figures 47-50. First, the general equilibrium trade costs are large. Second, by construction, the GETCs and the total trade costs are inversely related. The intuition for this result is essentially the multilateral resistance argument from Anderson and van Wincoop (2003); all else equal, two countries will trade more with each other the more remote they are from the rest of the world. As discussed in detail in Yotov et al. (2016) a very similar argument applies to the general equilibrium impact of trade liberalization; for example, when two countries sign a free trade agreement, they become closer with each other but they also become further apart form the rest of the world. These forces are reflected in the structural GETC indexes. Finally, the results from Table 12 and Figures 47-50 reveal that the GETCs and their evolution over time are quite heterogeneous across sectors with manufacturing

Table 12: *General Equilibrium Trade Costs per Sector, 1995-2011*

		Total Trade Costs per Sector			
Sector Description	Mean	1995	2003	2011	%Δ95/11
Sector Description	GETC	GETC1995	GETC2003	GETC2011	pch
Agriculture, Hunting, Forestry and Fishing	0.19	0.14	0.21	0.18	24.58
Mining and Quarrying	0.87	0.16	2.03	0.16	-2.94
Food, Beverages and Tobacco	0.21	0.26	0.25	0.14	-45.48
Textiles and Textile Products	0.25	0.09	0.11	1.00	977.41
Leather, Leather Products and Footwear	0.42	0.24	0.47	0.65	168.16
Wood and Products of Wood and Cork	0.18	0.39	0.12	0.20	-48.20
Pulp, Paper, Printing and Publishing	0.08	0.07	0.07	0.07	0.98
Coke, Refined Petroleum and Nuclear Fuel	0.18	0.14	0.14	0.24	70.26
Chemicals and Chemical Products	0.15	0.11	0.14	0.22	92.25
Rubber and Plastics	0.14	0.12	0.13	0.16	35.59
Other Non-Metallic Mineral	0.20	0.22	0.12	0.34	55.51
Basic Metals and Fabricated Metal	0.10	0.07	0.08	0.14	105.97
Machinery, Nec	0.10	0.09	0.09	0.12	43.80
Electrical and Optical Equipment	0.18	0.15	0.18	0.26	74.18
Transport Equipment	0.26	0.43	0.20	0.19	-55.09
Manufacturing, Nec; Recycling	0.19	0.14	0.14	0.29	108.99
Electricity, Gas and Water Supply	8.47	0.42	48.88	0.13	-68.55
Construction	7.84	1.72	24.47	8.99	423.56
Sale, Maintenance and Repair of Motor Vehicles and Fuel	29.59	154.60	37.11	10.69	-93.09
Wholesale Trade and Commission Trade, Except of Motor Vehicles	0.82	5.52	0.12	0.15	-97.37
Retail Trade, Except of Motor Vehicles; Repair of Household Goods	18.51	145.44	6.93	5.80	-96.01
Hotels and Restaurants	12.50	4.61	1.79	0.55	-88.17
Inland Transport	12.19	0.07	0.06	1.68	2,432.83
Water Transport	16.35	0.24	11.29	96.48	40,943.12
Air Transport	1.25	0.11	4.54	0.15	28.09
Other Supporting and Auxiliary Transport Activities and Agencies	0.73	0.17	1.17	0.22	27.91
Post and Telecommunications	0.23	0.18	0.21	0.39	125.00
Financial Intermediation	0.18	0.29	0.14	0.19	-34.66
Real Estate Activities	3,597.67	10,279.07	1,479.85	1,222.93	-88.10
Renting of MandEq and Other Business Activities	0.09	0.09	0.08	0.09	-1.56
Public Admin and Defence; Compulsory Social Security	1.83	1.59	3.34	0.89	-44.37
Education	1.69	3.74	0.88	1.44	-61.54
Health and Social Work	14.11	0.44	2.49	0.43	-1.72
Other Community, Social and Personal Services	0.97	0.76	1.51	2.13	181.80
Private Households with Employed Persons	13,759.79	217.72	170.95	183.31	-15.80

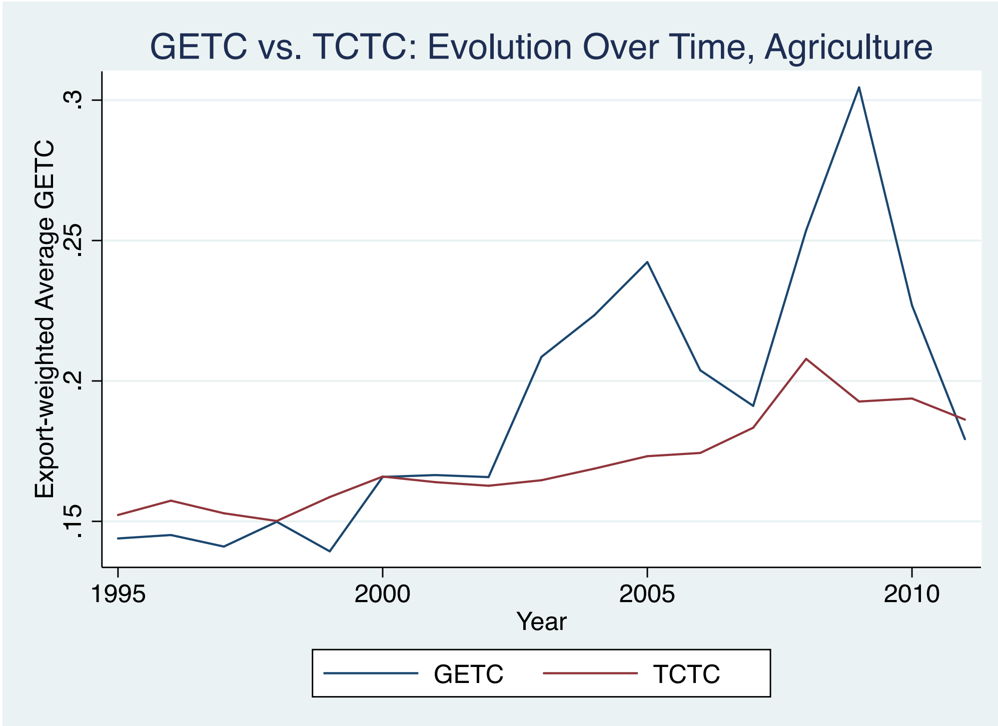


Fig. 47: *GETC vs. TCTC: Evolution Over Time, Agriculture*

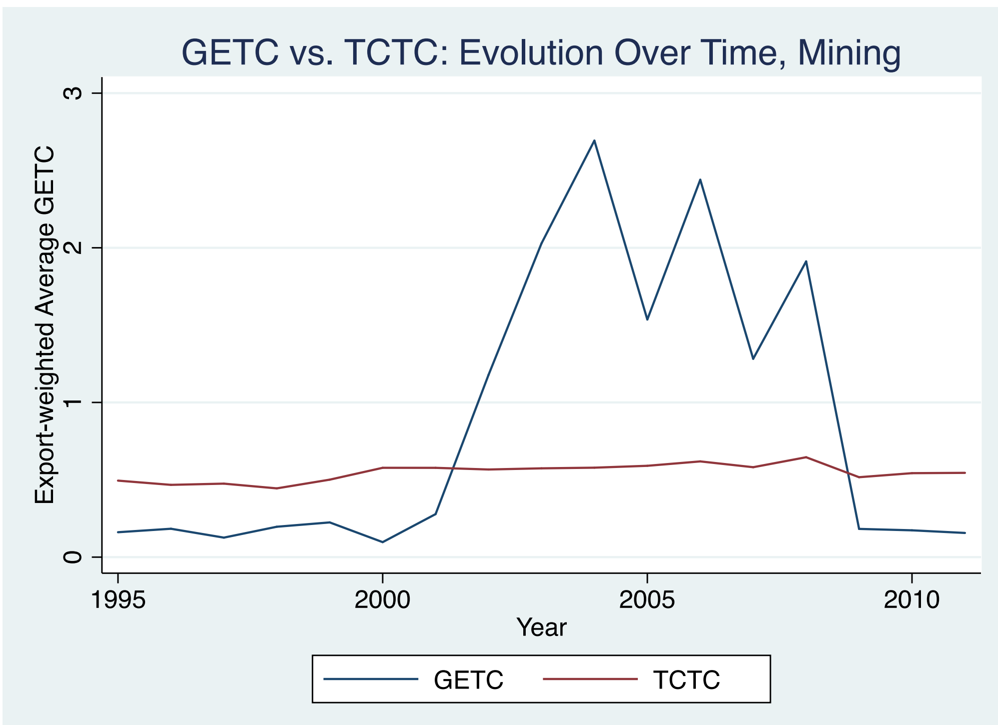


Fig. 48: *GETC vs. TCTC: Evolution Over Time, Mining*

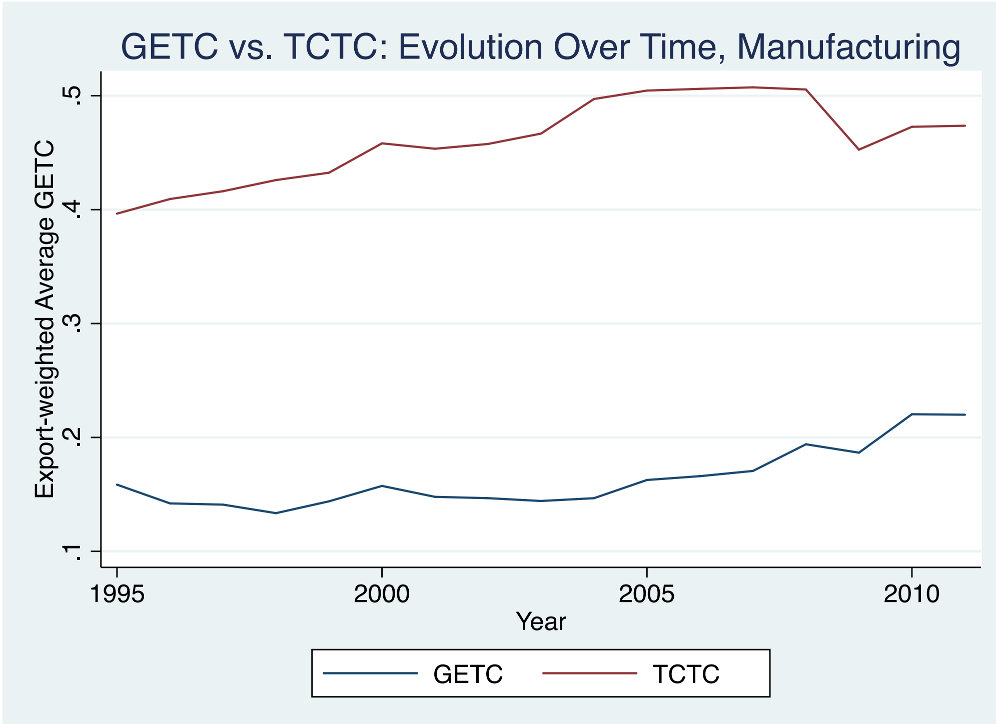


Fig. 49: *GETC vs. TCTC: Evolution Over Time, Manufacturing*

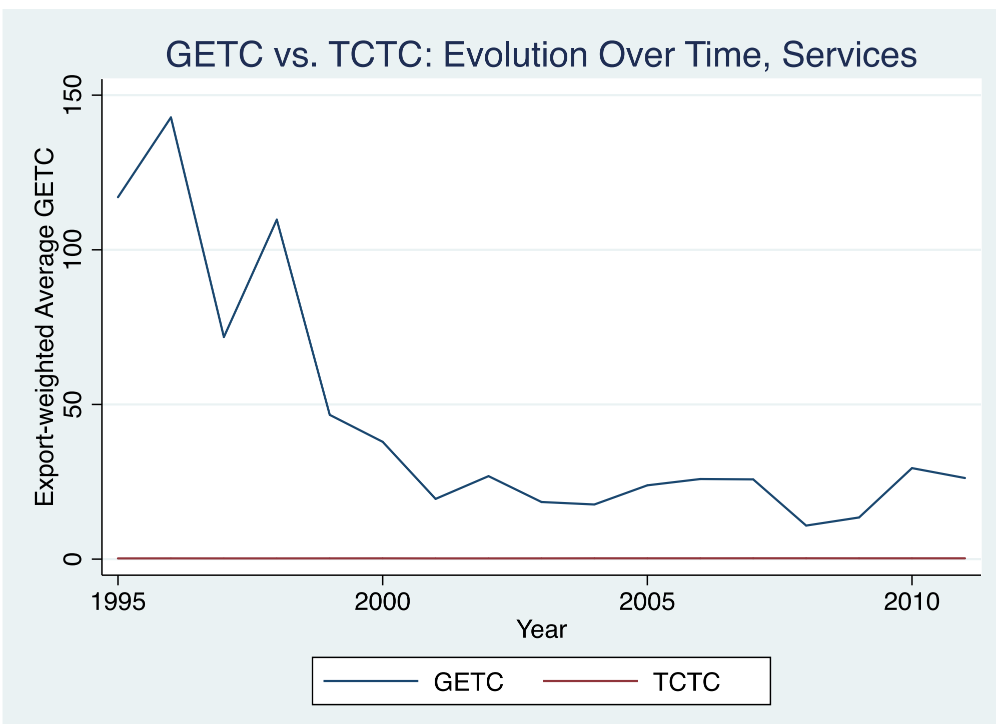


Fig. 50: *GETC vs. TCTC: Evolution Over Time, Services*

being the sector with most predictable and smooth behaviors and services being the sector with most volatile GETCs.

5.6 Decomposition of PETC and TCTC

In this section, we decompose the Partial Equilibrium Trade Costs (PETC) and the Total Calibrated Trade Costs (TCTC) that we obtained in the previous sections across skill groups for each country in our sample. In order to do so, we use two alternative measures, namely (i) labor compensation of low, medium and high skilled works as a share of total labor compensation as well as (ii) hours worked by low, medium and high skilled workers as a share of total hours worked. These data come from the WIOD Socio-Economic Accounts (SEA) (http://www.wiod.org/database/seas13), which are fully consistent with the World Input-Output Database (WIOD) that we use to construct our trade costs.

The labor compensation shares and shares of hours worked vary over countries, years and sectors. We use the country-sector variation to decompose the trade costs by first weighting trade costs in each country, sector and year by the compensation shares or shares of hours worked, and then aggregate over sectors using total exports of sectors as weights. We then end up with shares of trade costs by countries and years. The shares are pretty stable over the years. Hence, for brevity and clarity, we only report the averages over the years.

Table 13 reports results for the decomposition of Partial Equilibrium Trade Costs (PETC) over the skill groups for both weightings, the compensation shares and the shares of hours worked. The first column of Table 13 lists the ISO codes for the countries in our sample. Columns (2) to (4) report the shares of trade costs falling on low, medium and high skilled workers using hours worked for the decomposition. Table 13 reveals that by and large in countries that export skill-intensive products, like USA, Great Britain and France, a large share on the trade costs falls on high and medium skilled labor, while in countries that have a comparative advantage in low skilled labor production, like for example Bulgaria,

Table 13: *Decomposition of Partial Equilibrium Trade Costs (PETC) over Skill Groups*

	Hours Worked			Compensation		
ISO	low	medium	high	low	medium	high
AUS	0.48	0.40	0.13	0.40	0.42	0.18
AUT	0.19	0.67	0.13	0.14	0.67	0.19
BEL	0.34	0.53	0.13	0.31	0.51	0.18
BGR	0.70	0.18	0.12	0.60	0.19	0.22
BRA	0.43	0.39	0.18	0.28	0.34	0.39
CAN	0.06	0.78	0.16	0.05	0.75	0.20
CHN	0.41	0.50	0.09	0.38	0.50	0.12
CYP	0.33	0.40	0.28	0.28	0.35	0.36
CZE	0.08	0.82	0.10	0.06	0.77	0.16
DEU	0.18	0.62	0.20	0.12	0.57	0.31
DNK	0.26	0.53	0.21	0.22	0.53	0.25
ESP	0.51	0.21	0.28	0.44	0.20	0.36
EST	0.12	0.62	0.26	0.10	0.55	0.35
FIN	0.24	0.47	0.29	0.22	0.43	0.35
FRA	0.31	0.46	0.23	0.26	0.42	0.32
GBR	0.31	0.46	0.22	0.24	0.43	0.33
GRC	0.36	0.44	0.20	0.34	0.41	0.25
HUN	0.17	0.68	0.16	0.12	0.60	0.28
IDN	0.68	0.26	0.06	0.54	0.33	0.13
IND	0.44	0.41	0.14	0.33	0.42	0.24
IRL	0.30	0.44	0.26	0.25	0.43	0.32
ITA	0.49	0.41	0.09	0.45	0.42	0.14
JPN	0.10	0.64	0.26	0.09	0.58	0.33
KOR	0.26	0.50	0.24	0.24	0.46	0.30
LTU	0.10	0.68	0.22	0.08	0.61	0.31
LUX	0.39	0.45	0.16	0.34	0.44	0.22
LVA	0.13	0.67	0.20	0.10	0.59	0.31
MEX	0.30	0.53	0.17	0.16	0.60	0.25
MLT	0.79	0.15	0.06	0.71	0.17	0.12
NLD	0.37	0.45	0.18	0.30	0.45	0.25
POL	0.08	0.79	0.13	0.06	0.73	0.21
PRT	0.74	0.17	0.09	0.65	0.18	0.16
ROU	0.77	0.16	0.07	0.67	0.18	0.14
RUS	0.09	0.79	0.12	0.06	0.73	0.21
SVK	0.06	0.82	0.12	0.05	0.77	0.19
SVN	0.19	0.65	0.16	0.13	0.60	0.27
SWE	0.23	0.61	0.16	0.20	0.58	0.21
TUR	0.63	0.24	0.13	0.49	0.26	0.25
TPKM	0.48	0.33	0.19	0.43	0.32	0.25
USA	0.13	0.63	0.25	0.08	0.55	0.36

Indonesia, and Romania, the largest share of trade costs are born by low skilled labor. This pattern fits well with standard Heckscher-Ohlin explanations for trade based on factor endowment differences: countries with a relatively large share of low skilled labor should export low skill-intensive goods, while countries with a relatively large share of high skilled labor should export high skill-intensive goods. This export specialization pattern explains the corresponding decomposition of trade costs over skill groups.

A very similar pattern arises if we decompose using the labor compensation shares rather then the shares of hours worked. Compare columns (5)-(7) with columns (2)-(4) in Table 13.

We provide the same decompositions for Total Calibrated Trade Costs (TCTC) in Table 14. Comparing Tables 13 and 14 we see a very similar pattern. Hence, the decomposition of trade costs on consumers is very similar for PETC and TCTC. This means that the general equilibrium forces are not affecting the trade costs decomposition towards specific skill groups. Note that TCTC do not allow sectoral changes, as they take output and expenditure as given. Allowing for structural changes due to sectoral shifts by taking into account output and expenditure changes could lead to more pronounced differences between PETC and TCTC.

Table 14: *Decomposition of Total Calibrated Trade Costs (TCTC) over Skill Groups*

	Hours Worked			Compensation		
ISO	low	medium	high	low	medium	high
AUS	0.47	0.39	0.14	0.40	0.41	0.19
AUT	0.20	0.68	0.12	0.14	0.68	0.18
BEL	0.36	0.52	0.12	0.33	0.51	0.17
BGR	0.79	0.15	0.06	0.71	0.18	0.12
BRA	0.53	0.37	0.10	0.35	0.38	0.27
CAN	0.06	0.81	0.13	0.05	0.79	0.16
CHN	0.39	0.52	0.09	0.35	0.53	0.12
CYP	0.36	0.38	0.26	0.31	0.35	0.34
CZE	0.09	0.83	0.08	0.07	0.78	0.15
DEU	0.18	0.62	0.19	0.12	0.58	0.30
DNK	0.27	0.52	0.20	0.22	0.52	0.26
ESP	0.54	0.21	0.25	0.47	0.21	0.33
EST	0.13	0.63	0.24	0.10	0.57	0.33
FIN	0.24	0.49	0.27	0.22	0.45	0.33
FRA	0.33	0.48	0.19	0.27	0.44	0.29
GBR	0.29	0.47	0.24	0.22	0.43	0.34
GRC	0.38	0.42	0.20	0.35	0.39	0.25
HUN	0.18	0.71	0.11	0.13	0.64	0.23
IDN	0.65	0.28	0.07	0.52	0.33	0.15
IND	0.47	0.37	0.16	0.35	0.38	0.27
IRL	0.31	0.44	0.26	0.26	0.43	0.31
ITA	0.53	0.41	0.06	0.48	0.42	0.10
JPN	0.13	0.67	0.20	0.12	0.63	0.25
KOR	0.17	0.49	0.34	0.14	0.44	0.43
LTU	0.09	0.71	0.20	0.08	0.63	0.29
LUX	0.39	0.46	0.15	0.35	0.44	0.21
LVA	0.16	0.67	0.17	0.13	0.61	0.26
MEX	0.32	0.52	0.16	0.16	0.59	0.25
MLT	0.77	0.16	0.07	0.68	0.18	0.13
NLD	0.36	0.46	0.18	0.30	0.45	0.25
POL	0.09	0.81	0.11	0.07	0.75	0.18
PRT	0.80	0.15	0.05	0.71	0.18	0.11
ROU	0.80	0.15	0.05	0.72	0.17	0.11
RUS	0.09	0.82	0.09	0.06	0.76	0.18
SVK	0.07	0.85	0.08	0.06	0.80	0.14
SVN	0.21	0.67	0.12	0.15	0.63	0.22
SWE	0.24	0.62	0.13	0.22	0.60	0.18
TUR	0.71	0.22	0.08	0.58	0.25	0.17
TPKM	0.44	0.35	0.22	0.38	0.33	0.28
USA	0.12	0.65	0.23	0.08	0.58	0.34

6 Conclusions

The goal of this study is two-fold. First, it undertakes a rigorous, theory-guided approach towards quantifying general trade-cost concepts. The considered concepts include variable as well as fixed trade costs, tariff- as well as non-tariff variable trade costs, and partial (direct or immediate) trade-cost as well as general-equilibrium trade-cost effects. Beyond earlier work, the present study offers an account of trade costs with regard to different consumer types based on their income levels, and it proposes a similar approach on the supply side towards employees and workers with different skill levels. This decomposition enables an analysis of changes of the various trade-cost components as well as of the production factors and household types which bear those costs.

Second, the study offers programs and data which enable potential extensions as larger data-sets might become available in the future – regarding vintages of trade data so that the panel data-set on country-pair-sector tuples becomes longer, or potentially larger cross-sections of country-pair-sector data, etc. The set of results together with their discussion and the software programs should enable the interested reader to conduct analyses and research beyond the state of the art and what had been covered in the study itself. We hope that these opportunities make the study useful for users in the academic as well as the policy-maker domains.

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Appendix

A Derivation of Equation (8)

Start with:

$$X_{ij,t}^{sr} = B^s N_{i,t}^s \left(c_{i,t}^s \tau_{ij,t}^s b_{ij,t}^s\right)^{1-\sigma^s} \left(P_{j,t}^r\right)^{\sigma^s-1} E_{j,t}^r \int_{\phi_{ij}^{sr}}^{\infty} \phi^{\sigma^s-1} g_i^s(\phi) d\phi,$$

and use $g_i^s(\phi) = \theta^s h_i^s \phi^{-\theta^s-1}$:

$$\begin{aligned}
X_{ij,t}^{sr} &= B^s N_{i,t}^s \left(c_{i,t}^s \tau_{ij,t}^s b_{ij,t}^s\right)^{1-\sigma^s} \left(P_{j,t}^r\right)^{\sigma^s-1} E_{j,t}^r \int_{\phi_{ij}^{sr}}^{\infty} \phi^{\sigma^s-1} \theta^s h_i^s \phi^{-\theta^s-1} d\phi \\
&= B^s \theta^s h_i^s N_{i,t}^s \left(c_{i,t}^s \tau_{ij,t}^s b_{ij,t}^s\right)^{1-\sigma^s} \left(P_{j,t}^r\right)^{\sigma^s-1} E_{j,t}^r \int_{\phi_{ij}^{sr}}^{\infty} \phi^{\sigma^s-\theta^s-2} d\phi \\
&= B^s \theta^s h_i^s N_{i,t}^s \left(c_{i,t}^s \tau_{ij,t}^s b_{ij,t}^s\right)^{1-\sigma^s} \left(P_{j,t}^r\right)^{\sigma^s-1} E_{j,t}^r \left(\frac{1}{\sigma^s - \theta^s - 1} \phi^{\sigma^s-\theta^s-1} \Big|_{\phi_{ij}^{sr}}^{\infty} \right).
\end{aligned}$$

As $\sigma^s - \theta^s - 1 < 0$, we end up with:

$$X_{ij,t}^{sr} = B^s \theta^s h_i^s N_{i,t}^s \left(c_{i,t}^s \tau_{ij,t}^s b_{ij,t}^s\right)^{1-\sigma^s} \left(P_{j,t}^r\right)^{\sigma^s-1} E_{j,t}^r \frac{1}{\theta^s - \sigma^s + 1} \left(\phi_{ij}^{sr}\right)^{\sigma^s-\theta^s-1}.$$

Now we us $\phi_{ij,t}^{sr} = A^s \tau_{ij,t}^s \left(c_{i,t}^s b_{ij,t}^s\right)^{\frac{\sigma^s}{\sigma^s-1}} (P_{j,t}^r)^{-1} (E_{j,t}^r)^{\frac{1}{1-\sigma^s}} (f_{ij,t}^s)^{\frac{1}{\sigma^s-1}}$ to replace $\left(\phi_{ij,t}^{sr}\right)^{\sigma^s-1} = \left(A^s \tau_{ij,t}^s\right)^{\sigma^s-1} \left(c_{i,t}^s b_{ij,t}^s\right)^{\sigma^s} (P_{j,t}^r)^{1-\sigma^s} (E_{j,t}^r)^{-1} f_{ij,t}^s$:

$$\begin{aligned}
X_{ij,t}^{sr} =& B^s \theta^s \frac{1}{\theta^s - \sigma^s + 1} N_{i,t}^s h_i^s \left(c_{i,t}^s \tau_{ij,t}^s b_{ij,t}^s\right)^{1-\sigma^s} \left(P_{j,t}^r\right)^{\sigma^s-1} E_{j,t}^r \left(\phi_{ij}^{sr}\right)^{-\theta^s} \left(A^s \tau_{ij,t}^s\right)^{\sigma^s-1} \\
&\times \left(c_{i,t}^s b_{ij,t}^s\right)^{\sigma^s} (P_{j,t}^r)^{1-\sigma^s} (E_{j,t}^r)^{-1} f_{ij,t}^s \\
=& C^s N_{i,t}^s h_i^s c_{i,t}^s b_{ij,t}^s f_{ij,t}^s \left(\phi_{ij}^{sr}\right)^{-\theta^s},
\end{aligned}$$

where C^s again collects all all s-specific terms.

B Derivation of Price Index

Start with $p^s_{ij,t}(\phi) = p^s_{i,t}(\phi)\tau^s_{ij,t}b^s_{ij,t}$ and replace $p^s_{i,t}(\phi)$ using Equation (1) to obtain:

$$p^s_{ij,t}(\phi) = \frac{\sigma^s}{\sigma^s - 1}\frac{c^s_{i,t}\tau^s_{ij,t}b^s_{ij,t}}{\phi}.$$

The price index is given by:

$$\begin{aligned}
(P^r_{j,t})^{1-\sigma^s} &= \sum_i \sum_s N^s_{i,t} \int_{\phi^{sr}_{ij}}^{\infty} \left[p^s_{ij,t}(\phi)\right]^{1-\sigma^s} g^s_i(\phi)d\phi \\
&= \sum_i \sum_s N^s_{i,t} \int_{\phi^{sr}_{ij}}^{\infty} \left[\frac{\sigma^s}{\sigma^s - 1}\frac{c^s_{i,t}\tau^s_{ij,t}b^s_{ij,t}}{\phi}\right]^{1-\sigma^s} g^s_i(\phi)d\phi \\
&= \sum_i \sum_s N^s_{i,t} \int_{\phi^{sr}_{ij}}^{\infty} \left[\frac{\sigma^s}{\sigma^s - 1}\frac{c^s_{i,t}\tau^s_{ij,t}b^s_{ij,t}}{\phi}\right]^{1-\sigma^s} \theta^s h^s_i \phi^{-\theta^s - 1}d\phi \\
&= \sum_i \sum_s N^s_{i,t} \left[\frac{\sigma^s}{\sigma^s - 1}c^s_{i,t}\tau^s_{ij,t}b^s_{ij,t}\right]^{1-\sigma^s} \theta^s h^s_i \int_{\phi^{sr}_{ij}}^{\infty} \phi^{\sigma^s - 1}\phi^{-\theta^s - 1}d\phi \\
&= \sum_i \sum_s N^s_{i,t} \left[\frac{\sigma^s}{\sigma^s - 1}c^s_{i,t}\tau^s_{ij,t}b^s_{ij,t}\right]^{1-\sigma^s} \theta^s h^s_i \int_{\phi^{sr}_{ij}}^{\infty} \phi^{\sigma^s - \theta^s - 2}d\phi \Rightarrow
\end{aligned}$$

$$\begin{aligned}
(P^r_{j,t})^{1-\sigma^s} &= \sum_i \sum_s N^s_{i,t} \left[\frac{\sigma^s}{\sigma^s - 1}c^s_{i,t}\tau^s_{ij,t}b^s_{ij,t}\right]^{1-\sigma^s} \frac{\theta^s h^s_i}{\sigma^s - \theta^s - 1}\, \phi^{\sigma^s - \theta^s - 1}\Big|^{\infty}_{\phi^{sr}_{ij}} \\
&= \sum_i \sum_s N^s_{i,t} \left[\frac{\sigma^s}{\sigma^s - 1}c^s_{i,t}\tau^s_{ij,t}b^s_{ij,t}\right]^{1-\sigma^s} \frac{\theta^s h^s_i}{\theta^s - \sigma^s + 1}(\phi^{sr}_{ij})^{\sigma^s - \theta^s - 1},
\end{aligned}$$

where we used $\sigma^s - \theta^s - 1 < 0$.

Now use Equation (5), i.e.,

$$\phi^{sr}_{ij,t} = A^s \tau^s_{ij,t}\left(c^s_{i,t}b^s_{ij,t}\right)^{\frac{\sigma^s}{\sigma^s - 1}} (P^r_{j,t})^{-1}(E^r_{j,t})^{\frac{1}{1-\sigma^s}}(f^s_{ij,t})^{\frac{1}{\sigma^s - 1}}, \tag{60}$$

to obtain:

$$
\begin{aligned}
(P^r_{j,t})^{1-\sigma^s} =& \sum_i \sum_s N^s_{i,t} \left[\frac{\sigma^s}{\sigma^s-1} c^s_{i,t} \tau^s_{ij,t} b^s_{ij,t}\right]^{1-\sigma^s} \frac{\theta^s h^s_i}{\theta^s - \sigma^s + 1} \\
& \times \left(A^s \tau^s_{ij,t} \left(c^s_{i,t} b^s_{ij,t}\right)^{\frac{\sigma^s}{\sigma^s-1}} (P^r_{j,t})^{-1} (E^r_{j,t})^{\frac{1}{1-\sigma^s}} (f^s_{ij,t})^{\frac{1}{\sigma^s-1}} \right)^{\sigma^s-\theta^s-1} \\
=& \sum_i \sum_s N^s_{i,t} \left(\frac{\sigma^s}{\sigma^s-1}\right)^{1-\sigma^s} \frac{\theta^s h^s_i}{\theta^s-\sigma^s+1} (A^s)^{\sigma^s-\theta^s-1} (c^s_{i,t} b^s_{ij,t})^{1-\sigma^s+\frac{\sigma^s(\sigma^s-\theta^s-1)}{\sigma^s-1}} \\
& \times (\tau^s_{ij,t})^{1-\sigma^s+\sigma^s-\theta^s-1} (P^r_{j,t})^{-(\sigma^s-\theta^s-1)} \left((E^r_{j,t})^{\frac{1}{1-\sigma^s}} (f^s_{ij,t})^{\frac{1}{\sigma^s-1}} \right)^{\sigma^s-\theta^s-1} \Rightarrow
\end{aligned}
$$

$$
\begin{aligned}
(P^r_{j,t})^{-\theta^s} =& \sum_i \sum_s N^s_{i,t} \left(\frac{\sigma^s}{\sigma^s-1}\right)^{1-\sigma^s} \frac{\theta^s h^s_i}{\theta^s-\sigma^s+1} (A^s)^{\sigma^s-\theta^s-1} (c^s_{i,t} b^s_{ij,t})^{\frac{(1-\sigma^s)(\sigma^s-1)+\sigma^s(\sigma^s-\theta^s-1)}{\sigma^s-1}} \\
& \times (\tau^s_{ij,t})^{-\theta^s} \left((E^r_{j,t})^{\frac{1}{1-\sigma^s}} (f^s_{ij,t})^{\frac{1}{\sigma^s-1}} \right)^{\sigma^s-\theta^s-1} \\
=& \sum_i \sum_s N^s_{i,t} \left(\frac{\sigma^s}{\sigma^s-1}\right)^{1-\sigma^s} \frac{\theta^s h^s_i}{\theta^s-\sigma^s+1} (A^s)^{\sigma^s-\theta^s-1} (c^s_{i,t} b^s_{ij,t})^{1-\frac{\sigma^s\theta^s}{\sigma^s-1}} \\
& \times (\tau^s_{ij,t})^{-\theta^s} (f^s_{ij,t})^{1-\frac{\theta^s}{\sigma^s-1}} (E^r_{j,t})^{\frac{\theta^s}{\sigma^s-1}-1}.
\end{aligned}
$$

Collecting all s related terms in D^s and using Equation (11), i.e.,

$$
\begin{aligned}
D^s N^s_{i,t} h^s_i (c^s_{i,t})^{1-\frac{\theta^s\sigma^s}{\sigma^s-1}} &= \frac{Y^s_{i,t}}{\sum_j \sum_r (\tau^s_{ij,t})^{-\theta^s} (b^s_{ij,t})^{1-\frac{\theta^s\sigma^s}{\sigma^s-1}} (f^s_{ij,t})^{1-\frac{\theta^s}{\sigma^s-1}} (P^r_{j,t})^{\theta^s} (E^r_{j,t})^{\frac{\theta^s}{\sigma^s-1}}} \\
&= \frac{Y^s_{i,t}}{(\Pi^s_{i,t})^{-\theta^s}},
\end{aligned}
$$

leads to:

$$
(P^r_{j,t})^{-\theta^s} = \sum_i \sum_s (b^s_{ij,t})^{1-\frac{\sigma^s\theta^s}{\sigma^s-1}} (\tau^s_{ij,t})^{-\theta^s} (f^s_{ij,t})^{1-\frac{\theta^s}{\sigma^s-1}} (E^r_{j,t})^{\frac{\theta^s}{\sigma^s-1}-1} (\Pi^s_{i,t})^{\theta^s} Y^s_{i,t},
$$

where we used $D^s = C^s (A^s)^{-\theta^s}$, $C^s = B^s \frac{\theta^s}{\theta^s-\sigma^s+1} (A^s)^{\sigma^s-1}$, and $B^s = \left(\frac{\sigma^s}{\sigma^s-1}\right)^{1-\sigma^s}$.