Disentangling frictions across the world: markups versus trade costs[1]

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Abstract

We develop a structural framework that allows us to quantify the evolution of aggregate bilateral trade costs and markups over time. With minimal assumptions, we can disentangle aggregate markup and trade cost changes from observed changes in trade flows. We apply our method to trade data between 1990 and 2015 for the world's 100 largest economies. We find that across all country pairs, on average, bilateral aggregate markups have increased by 2.8% per year. As bilateral trade costs have fallen by 3.1% per year on average, we find a strong negative correlation between observed trade cost and markup changes. Markups have increased less in high-income countries than in other countries.

JEL-Classification: F10, F12, F14, F62, L13.

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1 Introduction

International trade is subject to frictions like transport costs as well as policies such as tariffs and nontariff barriers. Globalization has lead to a decline in international frictions, compared to intranational trade. In addition, easier access to foreign markets and increasing imports may have increased competition. At the same time, however, there is an increasing perception that markets have become less competitive, allowing firms to charge higher markups. The relative importance of these changes in aggregate trade costs and markups is unclear.

We are interested how both markup and trade cost frictions have developed, and we present empirical evidence on the relative changes of these two frictions over a period of 25 years on a country to country level. We find that trade frictions have indeed become smaller. At the same time, however, markup frictions have become larger. Thus, this paper complements two strands of the literature on frictions. One strand of the literature in international trade has developed quantitative trade models, and trade frictions and their changes have been scrutinized in structural gravity model in particular. These models aim at estimating the effects of globalization, in particular at quantifying by how much trade costs have fallen over time (for an overview, see Costinot and Rodríguez-Clare, 2014). In these models, all differences between international trade and intranational trade flows are explained by trade frictions in addition to trade diversion effects, and these models can explain trade patterns surprisingly well. Most models do not allow for markup changes, and those that do assume a certain market conduct. A part of this literature argues that introducing endogenous markups in such quantitative trade models is of a lesser importance, and trade cost changes continue to be the major drivers of bilateral trade flows.

On the other hand, the industrial organization (IO) literature has dealt with markups using detailed firm-level data. These papers estimate markups from a cost minimization approach and derive markups either for total sales or for domestic sales versus foreign sales, but not for bilateral market-to-market sales. This literature finds that markups have gone up substantially, contradicting the assumptions of standard quantitative trade models. For example, De Loecker et al. (2020) find that aggregate global markups have increased from 21% in 1980 to 61% in 2016. Other papers also find an increase in markups, see Calligaris et al. (2018), De Loecker et al. (2016), De Loecker and Eeckhout (2021), Díez et al. (2021),

and Keller and Yeaple (2020). While the quantitative trade literature typically abstracts from markups or assumes them to be constant, the IO literature typically abstracts from trade costs and does not specify country-to-country markups.

In this paper, we provide a framework that bridges both strands of the literature. To the best of our knowledge, we are the first to provide evidence on markup and trade cost changes at the country-to-country level.Our model relies on minimum assumptions of demand and supply. As for demand, it goes beyond the assumptions of structural gravity models which hold for a wide class of trade models.[1] The innovation is that we do not make any assumption on market conduct, but let the data tell us how markup frictions have developed compared to trade frictions.[2] As for supply, we only assume that each country does not waste any resources but operates on its (linear-homogeneous) aggregate production function. Thus, we do neither need any assumption on strategic (or non-strategic) behavior of firms nor have firms to be profit-maximizers. Under these minimal assumptions, we are able to disentangle the changes in trade and markup frictions. In this sense, our analysis provides a "forensic accounting" for all markup and trade cost changes as they have occurred in the world from 1990 to 2015.

We find that bilateral markups have increased by 2.8% per year, on average. At the same time, bilateral trade costs fell by 3.1% per year, on average, i.e., trade costs have decreased more than markups have gone up, and hence welfare has increased. This indicates that welfare gains from trade liberalization could have been larger if markup increases would not have partially compensated for the decline in trade frictions. Behind these average results, our results demonstrate the high degree of heterogeneity in changes in bilateral markups and trade costs across exporter, importers, and years.

We illustrate our research strategy in Figure 1. Trade flows X_{ijt} from country i to country j in period t determine bilateral, directional aggregate frictions θ_{ijt}. Quantities sold are then computed by division of trade flows by the respective aggregate friction times a country's unit cost, and aggregation gives us the aggregate production of a country. These quantities and the change in total factor productivity A_i will allow us to determine

[1]See Anderson (1979), Anderson and van Wincoop (2003), Anderson and Yotov (2016), Arkolakis et al. (2012), Bergstrand (1985), Caliendo and Parro (2015), Chaney (2008), Chor (2010), Costinot et al. (2012), Deardorff (1998), Eaton and Kortum (2002) and Helpman et al. (2008).

[2]Other papers have assumed specific modes of oligopolistic competition, see for example Amiti et al. (2019), Asprilla et al. (2019), Bernard et al. (2003), Breinlich et al. (2020), Feenstra and Weinstein (2017), Gaubert and Itskhoki (2021), Heid and Stähler (2024) and Hsu et al. (2020).

the trade cost changes $d\tau_{ijt}/\tau_{ijt}$. Since we also have the changes in aggregate frictions $d\theta_{ijt}/\theta_{ijt}$, the changes in markups $d\mu_{ijt}/\mu_{ijt}$ are the difference between the changes in aggregate frictions and the trade cost changes.

[Figure 1 about here.]

Consequently, the remainder of this paper is organized as follows. Section 2 develops the model that we use to determine aggregate frictions and their changes, and section 3 shows how we can disentangle trade and markup frictions, and how we can use our results to compute the welfare effects of changing frictions. Section 4 presents results, and section 5 concludes.

2 The model

The goal of our model is to disentangle aggregate trade cost and markup changes from aggregate bilateral trade data. In the following, we provide a theoretically consistent, micro-founded aggregation scheme of product-level trade flows. Importantly, we show that this aggregation scheme is based on cost shares, not revenue shares, avoiding endogeneity issues as revenues are a function of markups.

Consider a product $k(i)$ that is produced by a firm in country i for sale in country j. There are two types of frictions: First, any sale is subject to trade frictions $\tau_{ijk(i)} \geq 1$ that collect transport and transaction costs which are specific to the sale from country i to country j. These costs drive a wedge between the f.o.b. unit cost and the c.i.f. unit cost, and they are measured in the form of iceberg costs such that they inflate the f.o.b. unit cost denoted by $c_{ijk(i)}$ by factor $\tau_{ijk(i)}$.

Second, the firm selling product k may have market power which gives rise to a markup friction $\mu_{ijk(i)} \geq 1$. Contrary to the first friction, this represents no real cost but is the result of being able to exercise market power, and $\mu_{ijk(i)}$ measures—similarly to $\tau_{ijk(i)}$—by how much the firm is able to inflate the consumer price above the c.i.f. unit cost. Consequently, the firm will sell the product for a price

$$p_{ijk(i)} = \mu_{ijk(i)}\tau_{ijk(i)}c_{ijk(i)}, \tag{1}$$

implying sales of $x_{ijk(i)} = p_{ijk(i)}q_{ijk(i)}$ where $q_{ijk(i)}$ denotes the quantity sold. Let $\Psi_{ijk(i)} = \tau_{ijk(i)}c_{ijk(i)}q_{ijk(i)}$ denote the c.i.f. costs of these sales. In what follows, we will aggregate

on country-pair level, also because our empirical analysis uses the respective data, but it should be clear that our analysis also holds in industry (or any other) level as long as we can use a symmetric trade flow matrix that includes domestic trade.

The industrial organization literature uses firm-level data in order to compute an average markup across all destinations (or for domestic and foreign sales, if possible). If each firm sold one product only, the average markup would be given by $\mu_{ik(i)} = \sum_j \omega_j \mu_{ijk(i)}$ where $\omega_j \geq 0, \sum_j \omega_j = 1$, are the weights for this aggregation exercise.[3] Thus, this strand of the literature aggregates over all destinations, and while it can do so at the firm level, it cannot distinguish between different trade frictions across destinations. Using aggregate trade data, we aggregate over products but distinguish between destinations. In particular, aggregate sales, denoted by X_{ij}, are determined by a composite good with price $p_{ij} = \mu_{ij}\tau_{ij}c_i$ and quantity q_{ij} that adds up all sales for all products sold in country j that are produced in country i such that

$$X_{ij} = p_{ij}q_{ij} = \sum_{k(i)} x_{ijk(i)} = \sum_{k(i)} \mu_{ijk(i)}\tau_{ijk(i)}c_{ijk(i)}q_{ijk(i)} \tag{2}$$

holds. Let $\Psi_{ij} = \tau_{ij}c_i q_{ij}$ denote the aggregate c.i.f. costs of all sales from country i to country j. Division by Ψ_{ij} yields

$$\mu_{ij} = \sum_{k(i)} \frac{\mu_{ijk(i)}\tau_{ijk(i)}c_{ijk(i)}q_{ijk(i)}}{\tau_{ij}c_i q_{ij}} = \sum_{k(i)} \frac{\Psi_{ijk(i)}\mu_{ijk(i)}}{\Psi_{ij}} \tag{3}$$

and shows that the origin-destination-specific markup is a cost-weighted average of all origin-destination-product-specific markups.

Consequently, we consider a model in which each country i sells a composite good with quantity q_{ij} and value X_{ij} to country j and where $\theta_{ij} \equiv \mu_{ij}\tau_{ij}$ measures the *aggregate* frictions of exports from country i to country j, combining both trade cost and market power frictions.

To empirically measure how aggregate bilateral markups and trade costs change over time, i.e., to disentangle changes in θ_{ijt} into its individual components μ_{ijt} and τ_{ijt}, we need to identify the change in aggregate frictions for each country pair for each year t. At first glance, a gravity equation that uses a parametric trade friction specification seems like a

[3] In case of multi-product firms, the aggregation exercise extends to all products produced by the firm as only revenue data at the firm, not the firm-product, level are usually available.

good candidate. Specifying $\theta_{ijt}^{1-\sigma} = \mathbf{x}'_{ijt}\boldsymbol{\beta}$ is the parameterization standardly used in the gravity literature where σ is the elasticity of substitution which implies a trade elasticity of size $1-\sigma$. A downside of this specification is that typically used variables in $\mathbf{x}_{ijt}$ such as bilateral distance between countries, the existence of a regional trade agreement, etc. are symmetric. This would imply that the changes in aggregate frictions for sales from origin i to the destination market j are identical to the changes in aggregate frictions from destination j to the destination market i. What is more, most variables typically used for $\mathbf{x}_{ijt}$ are time-invariant (distance, common language, common colonial history,...), and even if they are time-varying such as having a regional trade agreement, they vary only seldomly. Furthermore, Egger and Nigai (2015) demonstrate that standard parametric trade friction functions suffer from omitted variable bias due to unobserved drivers of frictions. Finally, while these variable may have some meaning for an analysis of trade costs, they do not reflect any market power firms may have in a specific country. Since we want to identify aggregate frictions to begin with, it is not obvious what the impact of these typically used variables on markups could be, if there is any at all.[4]

To overcome these problems, we therefore use a semi-parametric constrained ANOVA approach following Egger and Nigai (2015) and decompose observed trade flows in the following way:

$$X_{ijt} = \exp\left(\eta_{it} + \nu_{jt} + \delta_{ijt}\right), \tag{4}$$

subject to the general equilibrium adding up constraints, i.e., $\sum_{i=1}^{n} X_{ijt} = \sum_{i=1} X_{jit} + D_j$, where D_j is country j's observed trade deficit. Note that η_{it} and ν_{jt} depend on δ_{ijt} due to the general equilibrium adding up constraint:

$$\exp\left(\eta_{it} + \nu_{jt}\right) \sum_{i=1}^{n} \exp\left(\delta_{ijt}\right) = \exp\left(\eta_{jt} + \nu_{it}\right) \sum_{j=1}^{n} \exp\left(\delta_{jit}\right) + D_j. \tag{5}$$

This decomposition approach has at least five advantages: it provides i) time-varying and ii) asymmetric measures of bilateral frictions $\exp(\delta_{ijt}) = \theta_{ijt}^{1-\sigma}$, iii) avoids measurement error in the frictions parameter due to unobserved determinants of aggregate frictions, iv) is consistent with adding up constraints imposed by standard estimators used in the

[4] A potential candidate would be an indicator of competition like the average Herfindahl-Hirschman Index (HHI) of a country. However, both markups and the HHI are determined jointly in equilibrium, so the HHI cannot be used as an explanatory variable that determines markups, as it is endogenous, see Miller et al. (2022).

gravity literature, see Fally (2015), and is v) consistent with standard general equilibrium quantitative trade models and the structural gravity equation. As an example, consider a generalized Armington model in which we allow for aggregate frictions instead of trade frictions only.[5] This model is—among many others— consistent with eq. (4).[6] In particular, this model appropriately captures the different components of the bilateral gravity equation such that we can identify the aggregate friction component in a consistent way:

$$X_{ijt} = \underbrace{\frac{Y_{it}}{Q_{it}^{1-\sigma} Y}}_{\exp(\eta_{it})} \underbrace{\frac{E_{jt}}{P_{jt}^{1-\sigma}}}_{\exp(\nu_{jt})} \underbrace{\theta_{ijt}^{1-\sigma}}_{\exp(\delta_{ijt})} \tag{6}$$

In (6), Y_{it} (Y) is country i's (world) sales, E_{jt} are country j's expenditures. P_{jt} and Q_{it} denote the inward and outward resistance terms, respectively, that accommodate the general equilibrium effects. The inward and outward resistance terms measure the ease by which consumers can purchase goods from all markets and the ease of producer access to all markets, respectively. In standard gravity parlance, η_{it} is the exporter fixed effect, ν_{jt} is the importer fixed effect, and δ_{ijt} indicates our object of interest, the aggregate frictions for sales from country i to country j.[7]

For each year t in our trade flow data set for n countries, including internal trade, eq. (4) is a separate system of n^2 equations with $n^2 + 2n$ unknowns, that is, $n^2\delta_{ij}$ bilateral friction parameters and n η_i inward resistance terms and n ν_j outward resistance terms. It is clear that without further restrictions, eq. (4) represents an underdetermined system of equations. We therefore introduce normalizations that are commonly used in the trade literature. It is well known that the solution to the system of equations of the multilateral resistance terms in a structural gravity model is only defined up to scale, see Anderson and Yotov (2010). We follow the suggestion by Yotov et al. (2016), p. 72, and normalize by the value of one inward multilateral resistance term, $\eta_1 = 0$. Being real models, we can only identify international frictions relative to internal frictions. We therefore follow

[5]This model is derived in detail in Appendix B.

[6]Besides an Armington model, eq. (4) is consistent with the models discussed in Arkolakis et al. (2012). Also note that eq. (4) is more general than the class of trade models discussed in Allen et al. (2020) as the latter only consider exogeneously given bilateral trade costs. Our decomposition holds even when allowing for endogenous markups.

[7]Computationally, this method can be implemented using STATA's `reg` command, when realizing that (6) represents a just identified system of (log-)linear system of equations, or, equivalently, a regression with an $R^2 = 1$ on a square data set of n^2 trade flows, including domestic trade, that are consistent with the adding up constraints.

Egger and Nigai (2015) and set $\delta_{ii} = 1$. As explained by Egger and Nigai (2015), in total, $n^2 - n - 1$ free bilateral friction parameters δ_{ij} can be identified.[8]

Once we have obtained the δ_{ijt}s separately for each year in our data set, we can transform them into aggregate frictions θ_{ijt} where we use $\sigma = 5$, a common value used in the trade literature, see, e.g., Anderson and van Wincoop (2003).[9]To take into account that internal trade costs may change over time, we have explored whether we should correct by changes in the producer price index (PPI) for domestic markets and by changes in unit costs to compute the change in domestically produced goods for the domestic market as $d \ln PPI_i = d \ln \theta_{ii} + d \ln c_i$ holds. However, we found that for all countries for which the producer price index for domestic markets and the unit costs are available, we cannot reject the hypothesis that $d \ln PPI_i = d \ln c_i$ holds, and therefore $d \ln \theta_{ii} = d \ln PPI_i - d \ln c_i \approx 0$, so that we continue to use the aggregate frictions from (4) without correction.[10]

3 Disentangling markups and trade costs

Once we have obtained the aggregate frictions θ_{ij} (and their changes) we consider the pricing of the representative firm in country i to the representative consumer in country j which is given by $p_{ij} = \theta_{ij} c_i$. If θ_{ij} were a pure trade friction, this would imply that any increase or decrease in trade frictions translates one to one into a price change. In models of perfect and Dixit-Stiglitz monopolistic competition, little or nothing changes: under perfect competition, prices are equal to c.i.f. unit costs such that $\mu_{ij} = 1$, and under monopolistic competition, markups stay constant, irrespective of the size of the trade costs (or their changes).

[8]Hence $n - 1$ values of δ_{ij} have to be normalized so we choose $n - 1$ reference country pairs. Note that asymptotically, i.e., when the number of countries in our sample goes to infinity, the share of country pairs in the data set needed as reference countries goes to 0, as $\lim_{n\to\infty} \frac{n-1}{n^2} = 0$. Hence, our normalization does not affect results in large samples. To minimize potential finite sample bias, we choose reference country pairs whose frictions have not changed to a significant extent during the sample period. For details on how we choose the reference country pairs, see Appendix A. The list of reference country pairs can be found in Table A.1 in Appendix A.

[9]$\sigma = 5$ is close to the estimated values of 4.927 of Gaubert and Itskhoki (2021) and 5.39 of Breinlich et al. (2020). Both papers employ structural, oligopolistic trade models to estimate σ. We probe the robustness of our results to different σ values in Section 4.

[10]We use the database of the OECD for the domestic producer price index (see OECD, 2022a) and the OECD unit labor cost index (see OECD, 2022b). The correlation between θ_{ijt} and $\tilde{\theta}_{ijt}$, which corrects for the different evolution of PPP_i and c_i, is 0.99 in our sample.

We relax this assumption and allow that markups may respond to trade cost or other changes in the competitive environment. To disentangle markup frictions μ_{ij} and trade frictions τ_{ij} (and their changes) from the data we observe, we need to infer output quantities from trade values. We measure output using the normalized unit cost $\theta_{ii}c_i = c_i$ as a numeraire such that $q_{ij} = X_{ij}/(\theta_{ij}c_i)$ implying $q_{ii} = X_{ii}$. From our θ_{ij}-estimates and the observed trade flows, we can then also determine aggregate production $q_i = \sum_j q_{ij}$. Note carefully that the ability to specify aggregate real output will also allow us to determine aggregate TFP changes in a consistent way.

To identify quantities, we use minimal assumptions. In particular, we do not need to make any assumption on market structures and firm behavior: each economy does not waste resources but operates on its production function. It chooses inputs z_i where z_i is the vector of k factors of production that lead to an output according to a linear-homogeneous production function $q_i = A_i f(z_i)$ such that unit costs are equal to marginal costs and where A_i denotes country i's total factor productivity. The variation in destination-specific marginal costs will allow us to disentangle trade and markup frictions. For this purpose, we have to identify which channels cause variation in marginal costs and hence prices over time besides the trade and the markup frictions we are interested in. In particular, we have to take into account that (i) factor prices and (ii) total factor price productivity change over time.

Therefore, we first determine changes in costs that are net of changes in factor prices and changes in output that are net of technological progress. In particular, the aggregate f.o.b. costs of the representative firm in country i are given by

$$C_i = \sum_k w_{ik} z_{ik}, \tag{7}$$

where w_{ik} denotes the factor price of production factor k in country i. If all production were shipped to country j, the c.i.f. costs would be equal to

$$C_{ij} = \tau_{ij} \sum_k w_{ik} z_{ik}. \tag{8}$$

In order to determine the destination-specific marginal costs and the respective markups, we now define the relevant change of this cost as

$$\widetilde{dC_{ij}} = d\tau_{ij} \sum_k w_{ik} z_{ik} + \tau_{ij} \sum_k w_{ik} dz_{ik}, \tag{9}$$

where the difference to dC_{ij} is that we want to leave out changes in factor prices (see Hall, 2018, for a similar determination of marginal costs in a national context). Similarly, we want to determine output changes without output growth due to technological change such that the relevant output change is given by

$$\widetilde{dq_{ij}} = dq_{ij} - q_{ij}\frac{dA_i}{A_i}. \tag{10}$$

Having taken out any influence form factor price changes and total factor productivity, the relevant marginal cost for serving market j is given by $\widetilde{dC_{ij}}/\widetilde{dq_{ij}}$ (and equal to the unit cost c_i times the trade friction τ_{ij}), and consequently the destination-specific markup is given by

$$\mu_{ij} = \frac{p_{ij}}{\widetilde{dC_{ij}}/\widetilde{dq_{ij}}} \Leftrightarrow \mu_{ij}\widetilde{dC_{ij}} = p_{ij}\widetilde{dq_{ij}}. \tag{11}$$

Using (9) and (10) in (11) yields

$$\mu_{ij}\left[d\tau_{ij}\sum_k w_{ik}z_{ik} + \tau_{ij}\sum_k w_{ik}dz_{ik}\right] = p_{ij}\left[dq_{ij} - q_{ij}d\ln A_i\right]. \tag{12}$$

Note carefully that dividing expression (12) by μ_{ij} yields an equation which contains only the level and changes of trade frictions since $p_{ij}/\mu_{ij} = \tau_{ij}c_i$. We have relegated the details on how to derive the change in trade frictions to Appendix C which we summarize in

Proposition 1. *The trade cost changes are given by*

$$\begin{aligned} d\ln\tau_{ij} = {} & \frac{\frac{X_{ij}}{\theta_{ij}}}{\sum_l\left(\frac{X_{il}}{\theta_{il}}\right)}d\ln\left(\frac{X_{ij}}{\theta_{ij}}\right) - d\ln\left(\sum_l\left(\frac{X_{il}}{\theta_{il}}\right)\right) \\ & + \frac{\sum_l\left(\frac{X_{il}}{\theta_{il}}\right) - \frac{X_{ij}}{\theta_{ij}}}{\sum_l\left(\frac{X_{il}}{\theta_{il}}\right)}\left[d\ln A_i + d\ln c_i\right]. \end{aligned} \tag{13}$$

Proof. See Appendix C. □

Note carefully that we observe X_{ij} and have shown in section 2 how to derive the aggregate trade frictions θ_{ij}. In order to develop a better understanding for Proposition 1, let us (re-)use $q_{ij} = X_{ij}/\theta_{ij}c_i$ and assume that unit costs and TFP do not change, that is, $d\ln A_i = d\ln c_i = 0$. For this case, we can rewrite (13) as

$$d\ln\tau_{ij} = \frac{q_{ij}}{q_i}d\ln q_{ij} - d\ln q_i = \frac{dq_{ij} - dq_i}{q_i} \tag{14}$$

which shows that the trade friction change for trade from country i to j depends only on output changes. For example, suppose that country i's output increase in all destinations, including country i, were the same, that is, $dq_i = ndq_{ij} > 0$. In this case, $(dq_{ij} - dq_i)/q_i = -(n-1)dq_{ij}/q_i < 0$, implying that an output increase must go along with a trade cost decline. Thus, the change in trade costs goes along with changes in *outputs*, when corrected for unit cost and TFP changes, while the change in markups goes along with changes in *sales*.

To bring Proposition 1 to the data, we need to measure the change in a country's TFP over time. Standard TFP measures rely on the Solow residual, i.e., the part of output growth that cannot be attributed to input factor growth. A prominent application of this approach are, e.g., the Penn World Tables by Feenstra et al. (2015). They construct TFP using a Törnqvist index that relates real GDP to technology and production factors to second order approximate any linear-homogenous production function, $Y_{it}^r = B_{it} f_{it}(\mathbf{z}_{it})$, where $\mathbf{z}_{it}$ is a vector of production factors, labor and capital.[11] TFP is then measured as the increase in real GDP that cannot be accounted for by factor accumulation, i.e.,

$$d \ln B_{it} = d \ln Y_{it}^r - \sum_k \alpha_{ikt} d \ln z_{ikt}. \tag{15}$$

However, this is only true under perfect competition or constant markups, and hence it is inconsistent with our framework. We therefore derive a correction term to standard TFP measures that corrects for the TFP mismeasurement due to imperfect competition. Production in our model is given by

$$\ln q_{it} = \ln A_{it} + \sum_k \alpha_{ikt} \ln z_{ikt}. \tag{16}$$

Note the difference between q_{it} and Y_{it}^r as an increase or decrease in $Y_{it} = \sum_j X_{ijt}$ can also be driven by markup changes. Hence, the TFP change that is not contaminated by markup changes is given by

$$d \ln A_{it} = d \ln q_{it} - \sum_k \alpha_{ikt} d \ln z_{ikt}. \tag{17}$$

[11] For the validity of this approximation and the Törnqvist index see Diewert (1976).

Subtracting (15) from (17) yields

$$\underbrace{d\ln A_{it}}_{\substack{\text{TFP change under}\\ \text{imperfect competition}}} = \underbrace{d\ln B_{it}}_{\substack{\text{TFP change under}\\ \text{perfect competition}}} + \underbrace{d\ln q_{it} - d\ln Y_{it}^r}_{\text{correction term}}. \tag{18}$$

Hence, we can derive TFP measures consistent with our theoretical framework that correct for the bias introduced by imperfect competition by combining standard TFP and real GDP growth measures, $d\ln B_{it}$ and $d\ln Y_{it}^r$, such as those from the PWT with the quantity growth measures, $d\ln q_{it}$, derived from our trade data. The Solow residual $d\ln B_{it}$ and the real GDP growth $d\ln Y_{it}$ are provided by the PWT, and our model provides the real output change $d\ln q_{it}$, so we can compute the true TFP change $d\ln A_{it}$.

Finally note that plugging eq. (18) into eq. (13) allows us to compute trade cost changes as

$$\begin{aligned} d\ln\tau_{ij} = {} & \frac{\frac{X_{ij}}{\theta_{ij}}}{\sum_l\left(\frac{X_{il}}{\theta_{il}}\right)} d\ln\left(\frac{X_{ij}}{\theta_{ij}}\right) - d\ln\left(\sum_l\left(\frac{X_{il}}{\theta_{il}}\right)\right) \\ & + \frac{\sum_l\left(\frac{X_{il}}{\theta_{il}}\right) - \frac{X_{ij}}{\theta_{ij}}}{\sum_l\left(\frac{X_{il}}{\theta_{il}}\right)}\left[d\ln B_i + d\ln\sum_l\left(\frac{X_{il}}{\theta_{il}}\right) - d\ln Y_i^r\right], \end{aligned} \tag{19}$$

where we have made use of the fact that $d\ln q_i = d\ln\sum_j(X_{ij}/\theta_{ij}) - d\ln c_i$.

We can then finally derive the change in markup frictions as

$$d\ln\mu_{ij} = d\ln\theta_{ij} - d\ln\tau_{ij}. \tag{20}$$

Thus, equations (19) and (20) allow us to disentangle the change of aggregate frictions into trade and market power friction changes for all source and destination countries.

We can complement our analysis by a welfare analysis if we are willing to make further assumptions on demand. In Appendix D, we generalize the welfare formula of Arkolakis et al. (2012) and show that welfare changes for a country can be given by

$$\widehat{W}_j = \widehat{E}_j\widehat{\Lambda}_j^{\frac{1}{1-\sigma}} = \frac{\widehat{E}_j\widehat{\lambda}_{jj}^{\frac{1}{1-\sigma}}}{\widehat{c}_j\widehat{\theta}_{jj}}. \tag{21}$$

Eq. (21) shows that—as in Arkolakis et al. (2012)—the welfare change can be computed using domestic changes only: it depends positively on the change in expenditures $\widehat{E}_j$, and

negatively on the change in domestic unit costs $\widehat{c}_j$ and the change in aggregate domestic frictions $\widehat{\theta}_{jj}$. Furthermore, an increase in the expenditure share of domestic goods, denoted by $\widehat{\lambda}_{jj}$, reduces the gains from trade as the country moves closer to autarky.

To gain intuition, consider a counterfactual change of trade cost frictions while keeping domestic expenditure, expenditure shares and production costs constant, i.e., $\widehat{E}_j = \widehat{\lambda}_{jj} = \widehat{c}_j = 1$, essentially doing partial equilibrium analysis. We can then compare welfare changes with and without markups changing, i.e., we investigate how welfare had changed if market power had not changed, but only the trade frictions affected welfare. Setting $\widehat{\theta}_{jj} = \widehat{\tau}_{jj}$ allows us to compute the counterfactual welfare change, denoted by $\widehat{W}_j^*$, as

$$\widehat{W}_j^* = \widehat{W}_j \widehat{\mu}_{jj}. \tag{22}$$

Eq. (22) shows that the change in the domestic markups, $\widehat{\mu}_{jj} = \widehat{W}_j^*/\widehat{W}_j$, indicates by how much the welfare change would be smaller (or larger) if markups had stayed constant. This relationship allows to infer how taking into account markup changes affects the welfare effects of trade cost changes observed in the data. Thus, a markup increase also indicates the potential loss in welfare increase. Of course, in a full general equilibrium analysis, we cannot assume that all other variable changes stay constant if markups do. However, an increase in market power is likely to imply more distortions and larger deadweight losses, and we would thus expect that $\widehat{E}_j$ to become larger and $\widehat{\lambda}_{jj}$ to become smaller with smaller markup increases. Therefore, (22) is a lower bound in this context. Having described our model, we bring it to the data in the next section.

4 Results

This section presents key results of our empirical exercise. We calculate θ_{ijt} for the largest 100 exporting countries using bilateral trade data from the Eora26 database by Lenzen et al. (2012) and Lenzen et al. (2013).[12] A key advantage of Eora26 is that it provides domestic trade data. We use data from 1990 to 2015, the time period available in the public version of Eora26.[13]

To measure the change in TFP consistent with a perfect competition framework, $d \ln B_i$ in eq. (13), we use the Penn World Tables 10.0 (PWT) by Feenstra et al. (2015). We use

[12]These represent 99.3% of world sales in Eora26 for the year 2015.

[13]See https://www.worldmrio.com.

the TFP measure at current PPPs (variable "ctfp").[14] Arguably, $d \ln B_i$ is the most widely used measure of TFP changes in the literature. Using our model, we can adjust the PWT TFP changes by applying our correction term given by eq. (18) and calculate TFP changes consistent with our imperfect competition framework. Figure 2 shows kernel density plots of the annual changes in the two TFP measures. In comparison to the PWT TFP measure, our corrected TFP implies an average annual change in TFP across all countries of 3.7% (median 3.6%), whereas the PWT annual TFP change averages 0.3% (median 0.5%). Our TFP measure also varies more, with a standard deviation of 0.15 (PWT 0.05). Our results are consistent with Crouzet and Eberly (2021) who also find that accounting for markups corrects a downward bias in conventional TFP growth measures.

[Figure 2 about here.]

[Figure 3 about here.]

While different in levels, the annual change of our corrected TFP measure is positively correlated with the annual change of the standard PWT TFP measure (correlation of 0.36, 0.29 if one includes outliers), see Figure 3. The positive but moderate correlation shows that applying our correction term does make a difference for TFP measurement. Importantly, our results show that—on average—unit cost reductions implied by productivity increases are not passed on completely to consumers. Not correcting the Solow residual implies that part of technological progress that is appropriated by firms with market power goes unrecorded.

Armed with our TFP measures, we can calculate annual trade cost and markup changes. First, we illustrate how year-to-year markup and trade cost changes are distributed. Figure 4 shows the density plot of all year-to-year markup changes.[15] We find that markup changes have been positive on average with a mean of 2.8% and a median of 2.6%. Figure 4 also shows that we observe some negative markup changes, and since median and mean do not differ much, the variation to either side is rather similar. Second, we compare this development with the change in trade costs. Figure 5 shows the density plot of all

[14] See https://www.ggdc.net/pwt.

[15] For ease of graphical depiction, we trim the data at the 2% and 98% percentile in both Figure 4 and Figure 5, similar to De Loecker and Eeckhout (2021). We also use the trimmed annual markup and trade cost changes for all other results presented.

year-to-year trade cost changes. Consistent with the findings in the trade literature, we find that bilateral trade costs have fallen on average, about 3.1% per year (median 3.0%). But this does not hold true in general as we also see some bilateral trade cost increases.

[Figure 4 about here.]

[Figure 5 about here.]

This immediately raises the question how markup and trade cost changes are correlated. For the year 2015, Figure 6 shows that the correlation between markup and trade cost changes is strongly negative.[16] While this observation does not establish any causality, it shows that at least parts of trade liberalization gains may have been compensated by markup increases. Figure 7 confirms this and shows the density of the year-to year changes. We can see that the trade cost changes have a lot of density in the area to the left of the peak while the opposite is true for markup changes. Standard gravity models that do not feature markups or assume that markups are constant identify gains from trade, which implies that the reduction in trade costs dominates the increase in markups we identify when allowing for endogenous markups. Thus, similar to standard analyses, we also observe a decrease in net aggregate frictions in our data.

[Figure 6 about here.]

[Figure 7 about here.]

[Table 1 about here.]

Besides these scatter plots, we regress the obtained (log) markup changes on the obtained (log) trade cost changes to gauge the relationship between markup and trade cost changes. We present results in Table 1, where column (1) presents the result of the pooled OLS regression. Trade cost changes "explain" about 20% of the variance of markup changes. In terms of magnitudes, a one percent decrease in trade costs increases markups by roughly 0.8%. Results are similar in the cross-section, see column (2), where we run the

[16] This result is not driven by the inclusion of domestic trade. When dropping domestic trade country pairs, the correlation remains basically unchanged, see Figure A.1 in Appendix E.

regression only on the last year in our sample. While the markup elasticity is of similar size (0.9%), trade cost changes explain about 28% of markup changes. To check whether this result is driven by domestic markup changes, we drop all domestic trade observations in columns (3) and (4). Again, results are similar.

We have used the change in our corrected TFP measure, $d \ln A_{i,t}$, that is consistent with our model of imperfect competition to construct the markup and trade cost changes for these regressions. Note that the resulting negative relationship between bilateral markup and trade cost changes does not hinge on using $d \ln A_{i,t}$. For comparison, we also compute markup and trade cost changes using the conventional measure of TFP changes from the PWT, $d \ln B_{i,t}$. We present results in Appendix F. Re-estimating Table 1 using the conventional TFP measure, we also obtain a markup elasticity of around 0.9% (see Table A.2).

Returning to our results using the corrected TFP measure, we can calculate the average pass-through from trade cost changes to prices. We know that for constant production costs,

$$\Delta \ln p_{ij} = \Delta \ln \mu_{ij} + \Delta \ln \tau_{ij}. \tag{23}$$

We find that the average year-to-year change in bilateral trade costs over the sample period, $\overline{\Delta \ln \tau_{ij}} = -0.031$ (see Figure 5), and the average change in markups, $\overline{\Delta \ln \mu_{ij}} = 0.028$ (see Figure 4), and hence eq. (23) implies that the average change in bilateral prices, $\overline{\Delta \ln p_{ij}} = \overline{\Delta \ln \mu_{ij}} + \overline{\Delta \ln \tau_{ij}} = 0.028 - 0.031 = -0.003$.

This means that a reduction of 3.1% of trade costs leads to a fall in prices by 0.3%, or, since $1 - (0.003/0.031) = 0.9$, a 90% pass-through to producers. Consequently, 90% of the trade cost reduction is "borne" by the producer, in this case, by augmenting its markup, whereas consumers only get a pass-through of 10%, i.e., they only benefit from a tenth of the trade cost reduction. This is in line with the results in Berman et al. (2012) who find a pass-through of 92% using detailed firm-level data. They find that pass-through works mostly through high productivity, large firms. This makes our results intuitive, as aggregate trade is driven by these large firms.

Our analysis provides us with year-to-year bilateral markup and trade cost changes. Taking these annual data, we can average them across markets, and then sum them up for each exporting country to obtain the accumulated average markup changes from 1990 to 2015. We depict these accumulated sales markup changes for all countries in our data set

in the map presented in Figure 8. Markups have gone up less in most European countries (between 5% and 32%), and more so in the Americas, particularly South America (between 31% to 77%, with Chile and Colombia observing increases of 96% and 94%). For example, whereas accumulated average markups have changed by 10% in Germany from 1990 to 2015, U.S. markups increased by 45% over the same period.

In general, high-income countries have seen smaller increases in markups compared to low and middle-income countries, see Figure 9, which presents kernel density plots of the same data.[17] For example, average accumulated Chinese markups increased by 70% during the sample period, and both Indian and Indonesian markups roughly increased by 85%. The exception are small, high-income oil-exporting countries such as Bahrein, Kuwait, Qatar, and Saudia Arabia, as well as Singapore and Panama, who all experienced a more than doubling in their respective accumulated average markups.

[Figure 8 about here.]

[Figure 9 about here.]

Importantly, our method also allows us to quantify bilateral changes in markups, i.e., the change in aggregate markups of a country in all its sales markets. As an illustration, we present the evolution of both sales markups and trade costs for the following selected countries from 1990 to 2015, where we set the level of both markups and trade costs in 1990 to 1: Australia, Belgium, Canada, the Netherlands, Germany, Spain, and the United States for their largest 12 sales markets (including their domestic market). We present results in Figures A.2 to A.8 in Appendix G.

We see that for many countries, sales markups have been increasing over time, but not for all countries or markets. For example, German markup evolution is heterogeneous across markets. We also find that domestic markups have changed relatively little in comparison with markups in the export markets. Whereas German markups increased only relatively little or even decreased, e.g., for exports to Poland, the Netherlands or Spain saw markups increase considerably. To the contrary, trade costs have fallen across the board: For all seven countries, trade costs to serve the top 12 markets have fallen. There is, however, substantial heterogeneity across exporters: While Australian, Dutch, Spanish,

[17]We use the World Bank's income group classification for the year 2015 to group countries.

and U.S. trade costs have roughly halved over the considered period, Germany's trade costs have only been reduced by about 20%. Overall, our results stress the heterogeneity in both bilateral markup and trade cost changes across importers, exporters, and years.

As we have shown in Section 3, the change in the domestic markup determines by how much welfare gains would be larger or smaller if markups had not changed. Figure 10 shows the accumulated change in domestic markups from 1990 to 2015. There is quite some variation across countries. Figure 10 implies that—on average—welfare gains would be 26% larger if markups had not increased.

[Figure 10 about here.]

Note carefully that the calculation above relies on the assumption that the expenditure change is the same in the counterfactual scenario. The effect on expenditure changes depends crucially on the effect of increased profits due to increased markups. Even if increased profits stayed completely in the country and added to income such that an increase in market power redistributes income from consumers to domestic firm owners, we expect that the associated deadweight losses will reduce aggregate expenditure. Furthermore, more competition should imply a decline in the expenditure share of domestically produced goods. Thus, Figure 10 probably gives a lower bound for the back-of-the envelope welfare calculation.

Our results may depend on the elasticity of substitution, σ, we use to calculate θ_{ijt}, and from which the bilateral markup and trade cost changes are derived. We therefore recalculate the implied markup and trade cost changes but use $\sigma = 3.8$, the median value of the meta study by Bajzik et al. (2020) and $\sigma = 6.03$, the preferred median value of the meta study by Head and Mayer (2014). Figure A.9 shows kernel density plots of the annual bilateral markup changes for the different σ values. A lower elasticity of substitution makes it easier for firms to increase their markups without losing too much revenue. Similarly, with low σ, if firms want to increase revenue, they have to slash markups considerably. Hence, as expected, we see fatter tails in the markup distributions for lower σ values. We present similar kernel density plots for the annual bilateral trade cost changes in Figure A.10. The three different kernel density plots appear to lie on top of each other. This does not mean that trade cost changes are invariant to σ, differences are just too small to be seen in the kernel density plot.[18] Using these alternative markup and trade

[18]Inspection of the values shows that the bilateral trade costs changes are indeed different across different

cost changes, we recalculate the accumulated bilateral markup changes as presented in Figures A.2 to A.8, see Figures A.11 to A.17. For comparison, we plot the baseline result in black. Comparing the figures reveals that we can see the results using $\sigma = 3.8$ as a conservative lower bound for the accumulated markup changes. Qualitatively, results are similar, independent of the particular value of σ, as changing the elasticity only rescales the respective markup and trade cost changes.[19]

5 Concluding remarks

This paper has developed a structural model which allows us to disentangle aggregate trade cost and markup frictions using aggregate trade data. Our approach makes minimal assumptions about supply and employs a generic structural model to compute aggregate trade frictions. We then apply this method to identify bilateral trade cost and markup frictions for the largest 100 exporters from 1990 until 2015. Our analysis is complementary to the existing literature on markups that uses firm-level data.

Consistent with this literature, we find that markups have increased; on average 2.8% per year. Quantitative trade models find a decline in trade cost frictions, and we also find this in our data: on average, trade costs fell by 3.1% per year, i.e., trade costs have decreased more than markups have gone up, and hence welfare has increased. But our findings also indicate that any welfare gain from trade liberalization could have been larger if markup increases would not have partially compensated for the decline in trade frictions. Beyond these averages, our results demonstrate the high degree of heterogeneity in changes in bilateral markups and trade costs across exporters, importers, and years.

Our paper deliberately employs a model that is quite general. This enables us to study the effects of globalization by distinguishing between trade frictions that arise due to distance, border effects and red tape, and markup frictions that arise due to market power. In our view, a major contribution of this paper is that our model is agnostic about market structure and conduct, enabling us to provide a detailed country-to-country "forensic

σ values, but only in the second or third digit.

[19] A rough rule of thumb can be derived by writing down the following ratio for two different elasticities: $d \ln \theta_{ijt}^{1-\sigma_1} / d \ln \theta_{ijt}^{1-\sigma_2}$, hence changes in aggregate frictions scale by a factor of $(1-\sigma_1)/(1-\sigma_2)$. For example, $\sigma_1 = 5$ and $\sigma_2 = 6.03$ implies that changes in frictions scale by a factor of $(1-5)/(1-6.03) \approx 0.8$.

accounting" of the trade cost and markup effects of international trade over 25 years. We have not explored what has driven this increase in markups. In future work, we intend to use the identified trade cost and markup changes to study the impact of specific trade policies on trade costs, and, importantly, markups, complementing the quantitative trade and structural gravity literature that has so far mostly abstracted from the competition effects of trade policy. We hope that our framework paves the way for other researchers to investigate these up-to-now less studied effects of trade liberalization.

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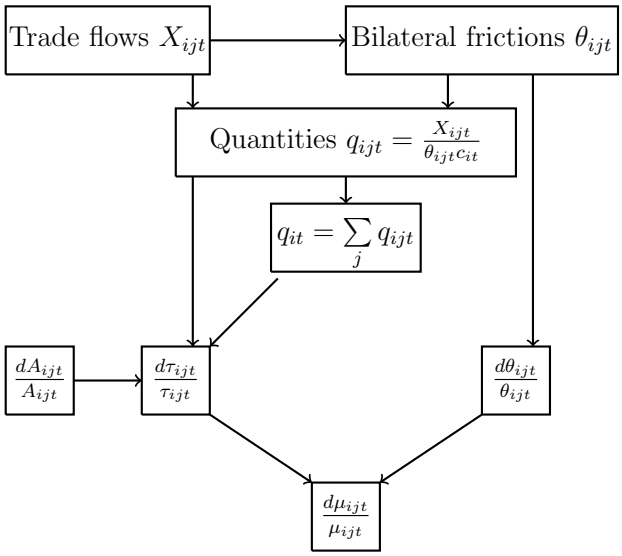


Figure 1: Howto of disentangling frictions

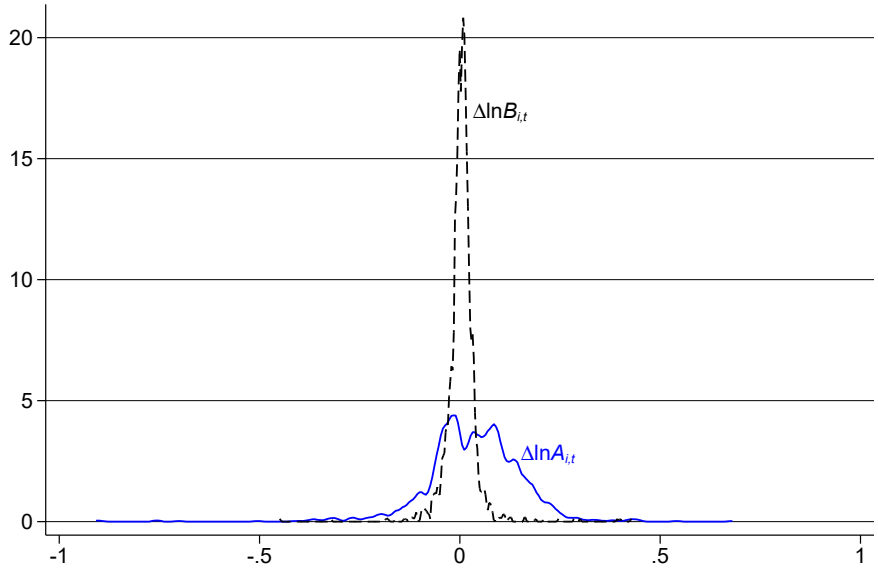


Figure 2: Kernel density plot of different TFP measure changes

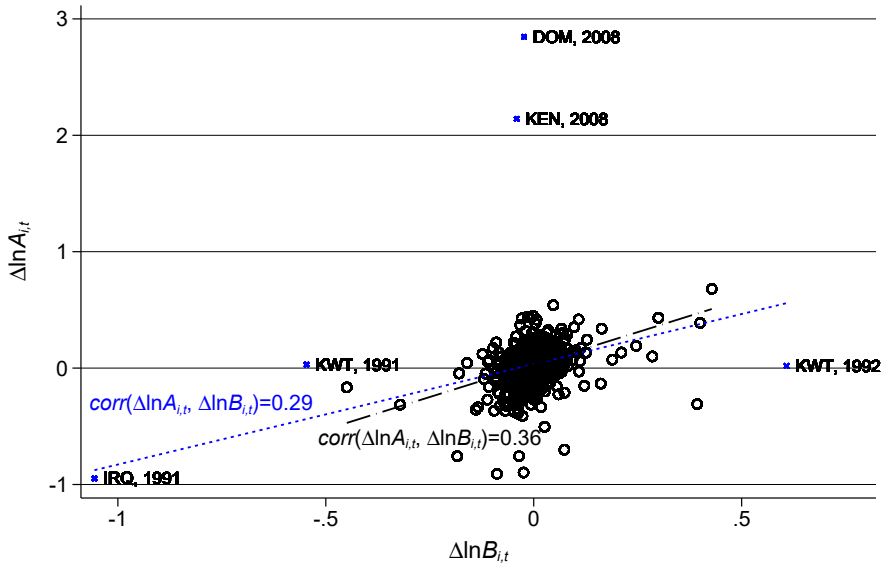


Figure 3: Scatter plot of different TFP measure changes

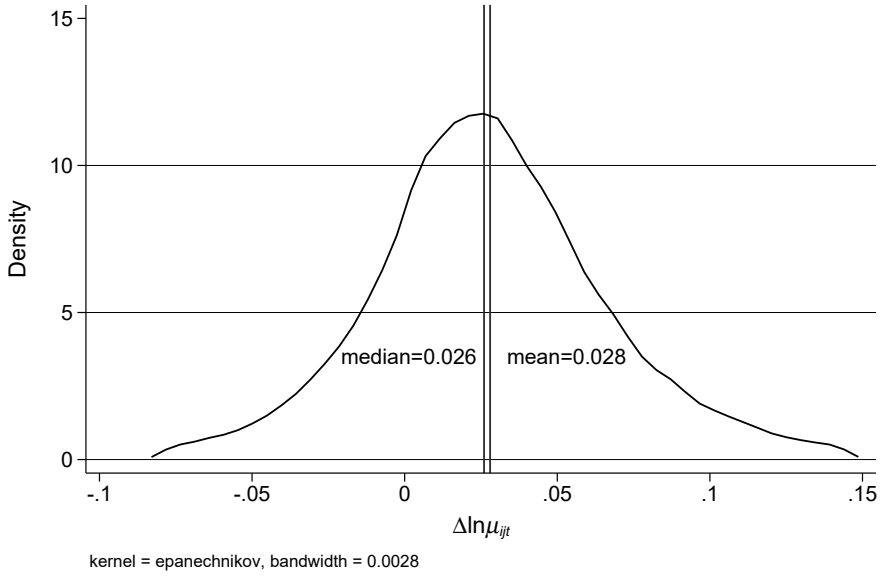


Figure 4: Kernel density plot of all markup changes

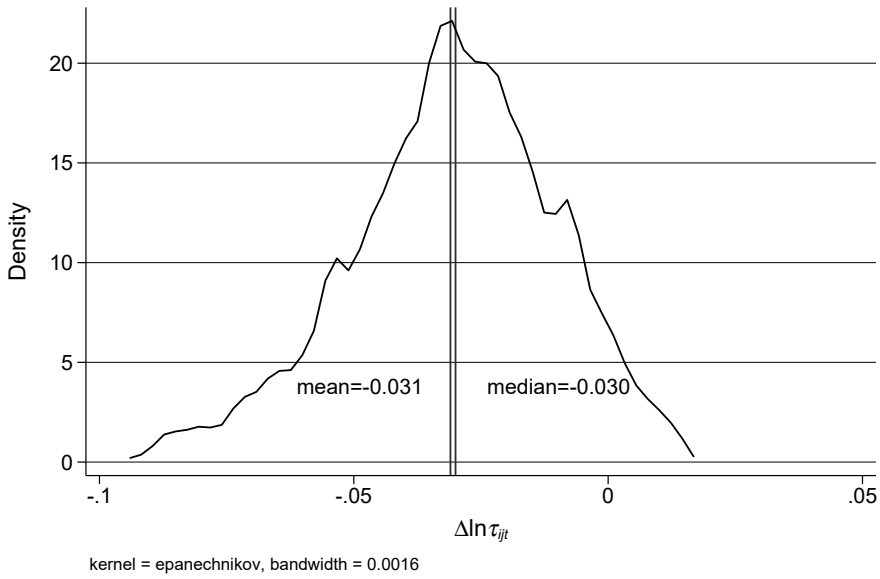


Figure 5: Kernel density plot of all trade cost changes

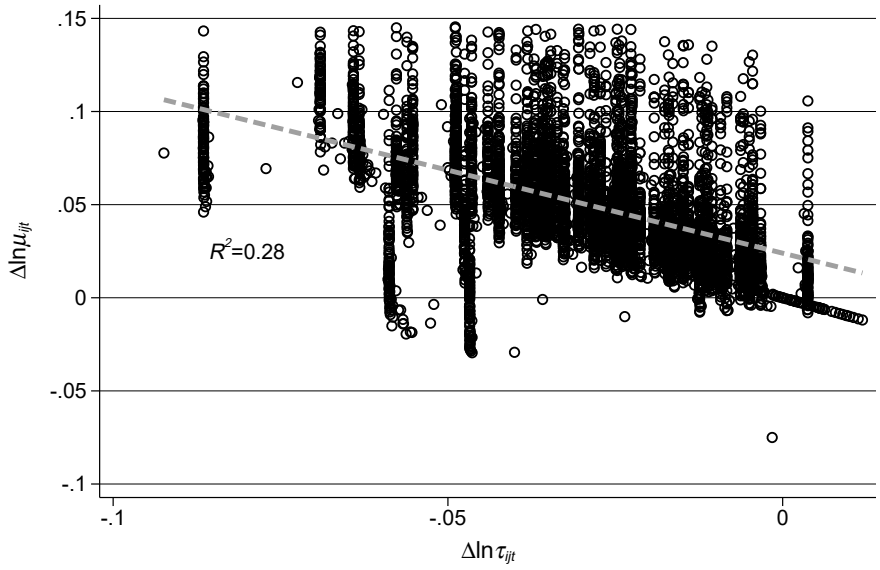


Figure 6: Year to year percentage changes in τ_{ijt} and μ_{ijt} for 2015

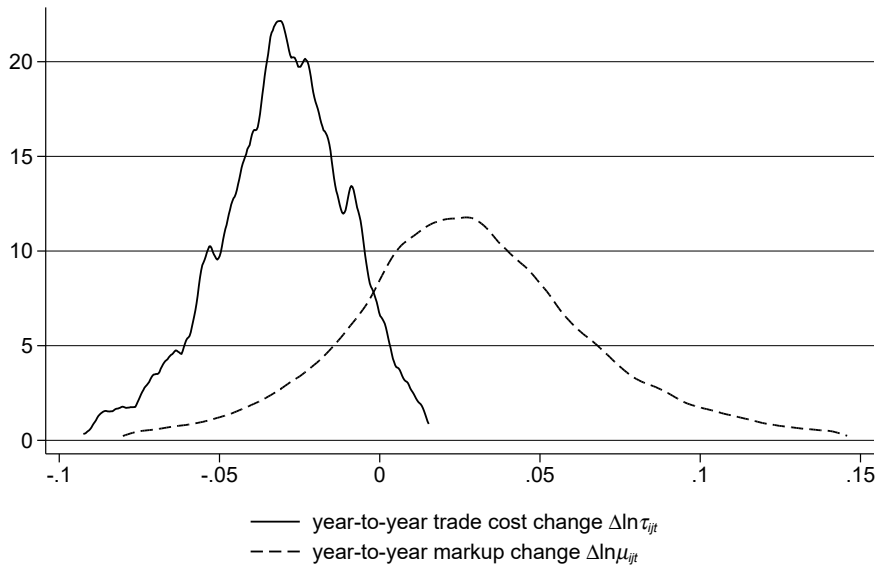


Figure 7: Distribution of year-to-year changes of bilateral trade cost and markup changes

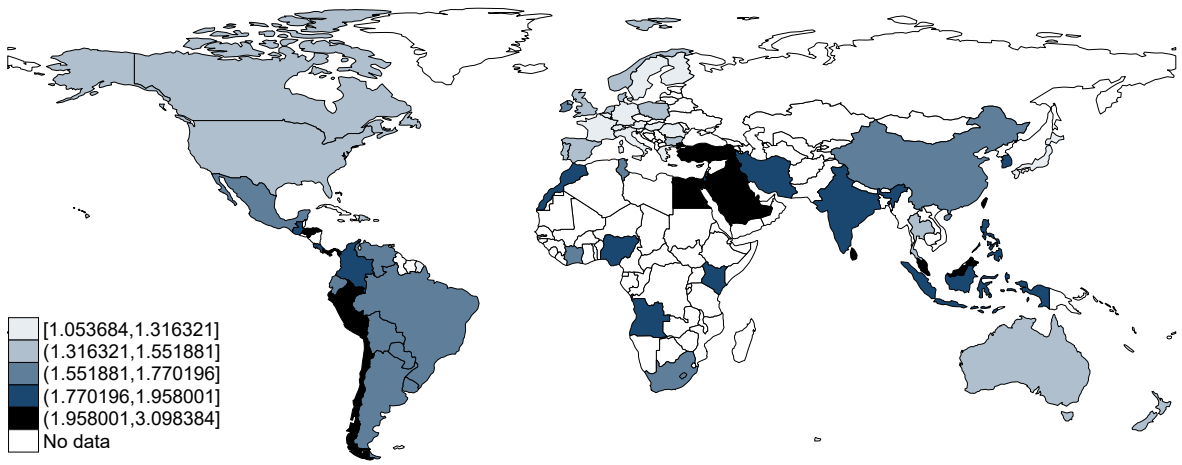


Figure 8: World map of accumulated average sales markup changes from 1990 to 2015, 1990=1

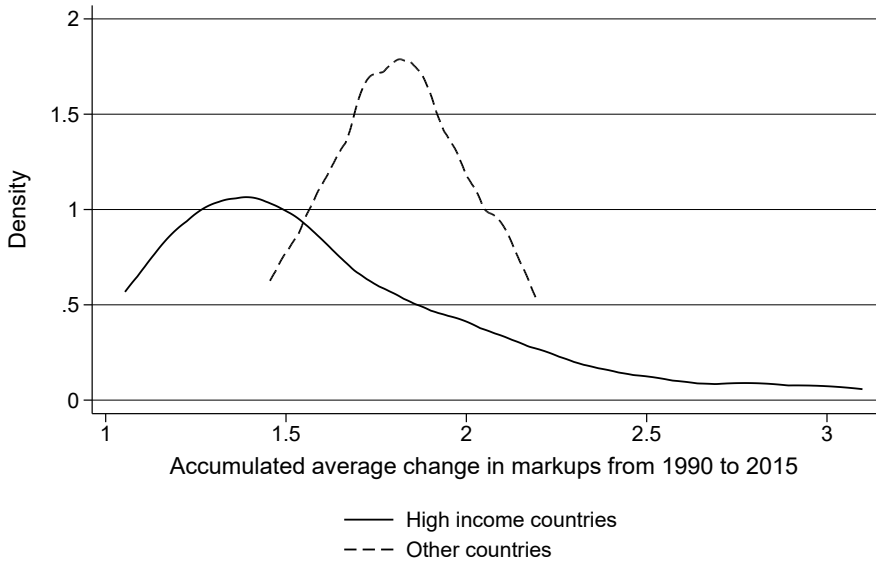


Figure 9: Kernel density plot of accumulated average sales markup changes from 1990 to 2015, 1990=1, for high-income countries and non-high-income countries

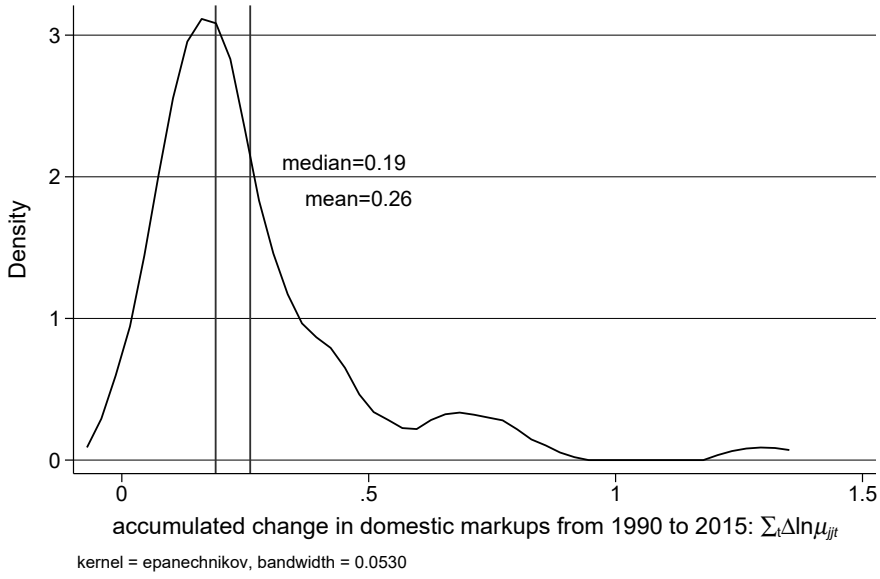


Figure 10: Distribution of accumulated domestic markup changes

Table 1: Relationship between markup and trade cost changes

dep. var.: $\Delta \ln \mu_{ijt}$	(1)	(2)	(3)	(4)
	1990–2015	2015	1990–2015	2015
	domestic and international trade		only international trade	
$\Delta \ln \tau_{ijt}$	−0.827***	−0.891***	−0.825***	−0.870***
	(0.031)	(0.119)	(0.031)	(0.121)
R^2	0.202	0.281	0.199	0.268
N	164517	6725	162853	6661

Notes: Table reports regression coefficients of regressing the annual log change in bilateral aggregate markups, $\Delta \ln \mu_{ijt}$, on the annual log change in bilateral aggregate trade costs, $\Delta \ln \tau_{ijt}$. All regressions include a constant that is not reported. Cameron et al. (2011) standard errors are robust to multiway clustering across exporters and importers. We use the `reghdfe` command by Correia (2017) in Stata 18.0. ** significant at the 5% level, *** significant at the 1% level.

Appendix

A Normalization of aggregate frictions

We determine reference country pairs such that country i is paired with country $j, j \neq i$, for which aggregate frictions between country i and country j remain stable such that we can set $d\delta_{ij} = 0$. At the same time, we have to make sure that the remaining δ_{ij}s do not become linearly dependent. We use the following algorithm to identify reference country pairs that comply with these requirements:

1. Calculate the sum of squared year-to-year log trade changes across the sample period for every (directional) country pair: $V_{ij} = \sum_t (\Delta \ln X_{ijt})^2$, N^2 values in total.
2. Identify the smallest values of V_{ij} for every exporting and for every importing country, $2N$ values in total. We call these country pairs "candidates".
3. Sort these values and keep the $N-1$ country pairs with the smallest values of V_{ij}.
4. Collect all distinct countries that form these country pairs in a set $\mathcal{C}$. If $|\mathcal{C}| = N$, where $|\cdot|$ denotes the cardinality of $\mathcal{C}$ (i.e., the number of elements in $\mathcal{C}$), the $N-1$

country pairs from step 3 are the set of $N-1$ reference country pairs. If $|\mathcal{C}| < N$, continue with the following steps.

5. Identify $\mathcal{M}$, the set of countries out of all N countries in the data set that are not included in $\mathcal{C}$. Add all country pairs involving these missing countries to the set of candidate country pairs.

6. Sort all candidate country pairs in increasing order of V_{ij}.

7. Starting with the lowest value of V_{ij}, again collect all distinct countries that form these country pairs in a set $\mathcal{C}$. If a country forming the candidate country pair is not already in $\mathcal{C}$, the country pair is a reference country pair. If both countries forming the country pair are already in $\mathcal{C}$, remove the country pair from the candidate pool.

8. Repeat this step with the next value of V_{ij} among the set of sorted candidates until $|\mathcal{C}| = N$.

We report the identified reference country pairs and their according V_{ij} value in Table A.1.

[Table A.1 about here.]

B A generalized Armington model

We develop the standard gravity equation with aggregate frictions following the seminal work of Anderson and van Wincoop (2003) in an environment introduced by Armington (1969). While this is arguably the simplest framework to derive an empirical measure of $d\ln\theta_{ij}$, our decomposition given by eq. (4) in the main text holds true in any model that arrives at an aggregate gravity equation.

In Armington models, the utility function of the representative consumer in country j is given by

$$U_j\left(q_{ij}\right) = \left(\sum_{i=1}^{n} q_{ij}^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}} \tag{A.1}$$

where q_{ij} denotes consumption of good i in country j, that is, country j's imports from country i, σ, with $\sigma > 1$, denotes the elasticity of substitution. Note that q_{jj} is country j's domestic trade.

The value of exports from country i to country j is denoted by $X_{ij} = p_{ij}q_{ij}$ where p_{ij} denotes the price for which the quantity q_{ij} sells in country j. We can rewrite the aggregate pricing behavior such that $p_{ij} = \theta_{ij}c_i$ holds where c_i is the unit cost of production in country i and θ_{ij} denotes the aggregate friction of trade between country i and country j; it is the surcharge on the free on board (f.o.b.) unit cost that producers in country i charge for consumers in country j. Note that our model is agnostic towards market structures, so we allow all kinds of market conduct to begin with as to be able to explain markup changes around the world.

The representative consumer takes prices as given, and utility maximization of (A.1) implies demands

$$q_{ij}^* = \frac{E_j \left(p_{ij}\right)^{-\sigma}}{\sum_{l=1}^{n} \left(p_{lj}\right)^{1-\sigma}} = \frac{E_j \left(c_i t_{ij}\right)^{-\sigma}}{\sum_{l=1}^{n} \left(c_l t_{lj}\right)^{1-\sigma}} = \frac{E_j \left(c_i t_{ij}\right)^{-\sigma}}{P_j^{1-\sigma}}, \tag{A.2}$$

where

$$P_j = \left[\sum_{i=1}^{n} \left(c_i \theta_{ij}\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \tag{A.3}$$

is the CES price index and E_j denotes country j's expenditures. The value of exports from country i to country j is equal to

$$X_{ij} = c_i \theta_{ij} q_{ij}^* = \left(\frac{c_i \theta_{ij}}{P_j}\right)^{1-\sigma} E_j, \tag{A.4}$$

and aggregate sales of country i, denoted by Y_i, are equal to the sum of all exports and domestic sales: $Y_i = \sum_{j=1}^{n} X_{ij}$. Thus,

$$Y_i = \sum_{j=1}^{n} X_{ij} = \sum_{j=1}^{n} \left(\frac{c_i \theta_{ij}}{P_j}\right)^{1-\sigma} E_j = c_i^{1-\sigma} \sum_{j=1}^{n} \left(\frac{\theta_{ij}}{P_j}\right)^{1-\sigma} E_j, \tag{A.5}$$

which can be rewritten as

$$c_i^{1-\sigma} = \frac{Y_i}{\sum_{j=1}^{n} \left(\frac{\theta_{ij}}{P_j}\right)^{1-\sigma} E_j} = \frac{\frac{Y_i}{Y}}{\sum_{j=1}^{n} \left(\frac{\theta_{ij}}{P_j}\right)^{1-\sigma} \frac{E_j}{Y}} \tag{A.6}$$

$$= \frac{Y_i/Y}{Q_i^{1-\sigma}} \text{ where } Q_i = \left[\sum_{j=1}^{n} \left(\frac{\theta_{ij}}{P_j}\right)^{1-\sigma} \frac{E_j}{Y}\right]^{\frac{1}{1-\sigma}} \tag{A.7}$$

is the outward multilateral resistance term and $Y = \sum_{j=1}^{n} Y_j$ are world aggregate sales. Replacing $c_i^{1-\sigma}$ in (A.4) yields the gravity equation as

$$X_{ij} = \frac{Y_i E_j}{Y} \left(\frac{\theta_{ij}}{Q_i P_j}\right)^{1-\sigma}. \tag{A.8}$$

C Proof of Proposition 1

Plugging in eqs. (9) and (10) and rearranging yields

$$d\ln\tau_{ij} = \frac{q_{ij}}{q_i} d\ln q_{ij} - d\ln q_i + \frac{q_i - q_{ij}}{q_i} d\ln A_i. \tag{A.9}$$

We know that

$$w_{ik} dz_{ik} = w_{ik} z_{ik} d\ln z_{ik} = c_i q_i \frac{w_{ik} z_{ik}}{c_i q_i} d\ln z_{ik} = c_i q_i \alpha_{ik} d\ln z_{ik} \tag{A.10}$$

where $\alpha_{ik} = w_{ik} z_{ik} / c_i q_i$ is the cost share of the factor of production k in country i. Furthermore, since $\sum_k w_{ik} z_{ik} = c_i q_i$ and $p_{ij} q_{ij} = \theta_{ij} c_i q_{ij} = \mu_{ij} \tau_{ij} c_i q_{ij}$, the markup equation can be rewritten as

$$\mu_{ij} \left[d\tau_{ij} c_i q_i + \tau_{ij} c_i q_i \sum_k \alpha_{ik} d\ln z_{ik} \right] = \mu_{ij} \tau_{ij} c_i \left[dq_{ij} - q_{ij} d\ln A_i \right]. \tag{A.11}$$

Divide by $\mu_{ij} c_i$ to get

$$d\tau_{ij} q_i + \tau_{ij} q_i \sum_k \alpha_{ik} d\ln z_{ik} = \tau_{ij} dq_{ij} - \tau_{ij} q_{ij} d\ln A_i. \tag{A.12}$$

Divide by τ_{ij}, and factor out q_i on the LHS and q_{ij} on the RHS to get

$$q_i \left[\frac{d\tau_{ij}}{\tau_{ij}} + \sum_k \alpha_{ik} d\ln z_{ik} \right] = q_{ij} \left[\frac{dq_{ij}}{q_{ij}} - d\ln A_i \right]. \tag{A.13}$$

We know that $d\ln q_i = d\ln A_i + \sum_k \alpha_{ik} d\ln z_{ik}$ or $\sum_k \alpha_{ik} d\ln z_{ik} = d\ln q_i - d\ln A_i$. Furthermore, let us use $d\ln\tau_{ij} = d\tau_{ij}/\tau_{ij}$ and $d\ln q_{ij} = dq_{ij}/q_{ij}$, so we arrive at

$$q_i \left[d\ln\tau_{ij} + d\ln q_i - d\ln A_i \right] = q_{ij} \left[d\ln q_{ij} - d\ln A_i \right] \Leftrightarrow \tag{A.14}$$

$$d\ln\tau_{ij} + d\ln q_i - d\ln A_i = \frac{q_{ij}}{q_i} \left[d\ln q_{ij} - d\ln A_i \right] \tag{A.15}$$

which yields

$$d\ln\tau_{ij} = \frac{q_{ij}}{q_i} \left[d\ln q_{ij} - d\ln A_i \right] - \left[d\ln q_i - d\ln A_i \right] \tag{A.16}$$

$$= \frac{q_{ij}}{q_i} d\ln q_{ij} - d\ln q_i + \frac{q_i - q_{ij}}{q_i} d\ln A_i. \tag{A.17}$$

Since $X_{ij} = \theta_{ij} c_i q_{ij}$, implying $q_{ij} = X_{ij}/(\theta_{ij} c_i)$, $\ln q_{ij} = \ln (X_{ij}//\theta_{ij}) - \ln c_i$ and $\ln q_i = \ln \left(\sum_j (X_{ij}//\theta_{ij}) \right) - \ln c_i$,

$$d \ln \tau_{ij} = \frac{\frac{X_{ij}}{\theta_{ij}}}{\sum_l \left(\frac{X_{il}}{\theta_{il}} \right)} d \ln \left(\frac{X_{ij}}{\theta_{ij}} \right) - d \ln \left(\sum_l \left(\frac{X_{il}}{\theta_{il}} \right) \right) \tag{A.18}$$

$$+ \frac{\sum_l \left(\frac{X_{il}}{\theta_{il}} \right) - \frac{X_{ij}}{\theta_{ij}}}{\sum_l \left(\frac{X_{il}}{\theta_{il}} \right)} \left[d \ln A_i + d \ln c_i \right] \tag{A.19}$$

which is (13).

D Welfare analysis

Country j's welfare is determined by the maximized utility of the representative consumer (see (A.1) in Appendix B) which can be written as $W_j = E_j / P_j(q_{ij}^*)$ and where the price index is given by

$$P_j = \left(\sum_{i=1}^{n} p_{ij}^{1-\sigma} \right)^{\frac{1}{1-\sigma}} = \left(\sum_i \left(c_i \theta_{ij} \right)^{1-\sigma} \right)^{\frac{1}{1-\sigma}}. \tag{A.20}$$

As in Arkolakis et al. (2012), let $\lambda_{ij} = X_{ij}/E_j = (c_i \theta_{ij})^{1-\sigma} / P_j^{1-\sigma}$ denote the expenditure share of goods imported from country i from which we can derive $\lambda_{ij}/\lambda_{jj} = (c_i \theta_{ij} / c_j \theta_{jj})^{1-\sigma}$. Consequently, we can write the changes in expenditure shares as

$$d \ln \lambda_{ij} - d \ln \lambda_{jj} = (1-\sigma) \left[d \ln c_i + d \ln \theta_{ij} - d \ln c_j - d \ln \theta_{jj} \right] \Leftrightarrow \tag{A.21}$$

$$d \ln c_i + d \ln \theta_{ij} = \frac{d \ln \lambda_{ij} - d \ln \lambda_{jj}}{1-\sigma} + d \ln c_j + d \ln \theta_{jj}. \tag{A.22}$$

We now totally differentiate the price index and use the above equation to show that the welfare change for country j depends only on the changes in $\theta_{jj}, \lambda_{jj}, c_j$ and E_j. We can write the change of P_j as

$$d \ln P_j = \sum_{i=1}^{n} \lambda_{ij} \left(d \ln c_i + d \ln \theta_{ij} \right) = \frac{d \ln \lambda_{jj}}{\sigma - 1} + d \ln c_j + d \ln \theta_{jj} \tag{A.23}$$

which follows from $\sum_{i=1}^{n} \lambda_{ij} d \ln \lambda_{ij} = \sum_{i=1}^{n} d \lambda_{ij} = 0$ and $\sum_{i=1}^{n} \lambda_{ij} = 1$. Let us now define $d \ln \Lambda_j = d \ln \lambda_{jj} + (\sigma - 1)[d \ln c_j + d \ln \theta_{jj}]$ such that we can write eq. (A.23) as a differential

equation which we can solve for the welfare change

$$\widehat{W}_j = \widehat{E}_j \widehat{\Lambda}_j^{\frac{1}{1-\sigma}} = \frac{\widehat{E}_j \widehat{\lambda}_{jj}^{\frac{1}{1-\sigma}}}{\widehat{c}_j \widehat{\theta}_{jj}}. \tag{A.24}$$

E Markups and trade cost changes without domestic trade

Figure 6 in the main text shows a scatter plot of markup and trade costs changes for the year 2015. We choose the last year in the sample to focus on the cross-sectional correlation. To exclude the possibility that the apparent correlation is driven by domestic markup and trade cost changes, Figure A.1 redraws the same scatterplot but omits domestic observations. Results are very similar, so our results are not driven by the inclusion of domestic trade.

[Figure A.1 about here.]

F Markups and Solow residual

Using the Solow residual in eq. (13) requires to calculate cost inflation. Considering factor price changes, the change in unit costs, $d \ln c_i$, is not directly observable. However, we can calculate it from the difference between nominal and real GDP. We can compute the output-side nominal GDP, Y_i, of country i as

$$Y_i = \sum_j X_{ij} = c_i \sum_j \theta_{ij} q_{ij} = c_i \sum_j \tau_{ij} \mu_{ij} q_{ij}. \tag{A.25}$$

Note that any increase in (i) trade costs, (ii) markups and (iii) quantities will increase the output-side nominal GDP. Let $Y_i^r = \sum_j \theta_{ij} q_{ij}$. Accordingly, we can calculate the change in unit costs as

$$d \ln Y_i = d \ln c_i + d \ln Y_i^r \Leftrightarrow d \ln c_i = d \ln Y_i - d \ln Y_i^r = d \ln \sum_j X_{ij} - d \ln Y_i^r. \tag{A.26}$$

To implement (A.26) in combination with (13), we calculate the change in total sales from our trade data, and use the (log) change in real GDP at constant 2017 national prices in USD from the PWT (variable "rgdpna"). We can then recalculate bilateral markup and trade cost changes and rerun the regressions presented in Table 1 in the main text. This yields Table A.2 which is based on the conventional TFP measure. Results remain similar to those in Table 1.

[Table A.2 about here.]

G Country-specific markup changes

Figures A.2 to A.8 present accumulated changes in markups and trade costs for selected countries for each country's top 12 sales destinations.

[Figure A.2 about here.]

[Figure A.3 about here.]

[Figure A.4 about here.]

[Figure A.5 about here.]

[Figure A.6 about here.]

[Figure A.7 about here.]

[Figure A.8 about here.]

H Results for different trade elasticities

Figures A.2 to A.8 in Appendix G show the evolution of the markup and trade cost changes for the baseline specification that sets the elasticity of substitution $\sigma = 5$. For comparison, we calculate markup and trade cost changes for other elasticity values typically used in the literature. Figure A.9 shows the distribution of markup changes for different σ values, and Figure A.10 compares trade cost changes. A.11 to A.17 present the accumulated changes for the same set of countries as in Appendix G. For comparison, we plot the baseline result in black.

[Figure A.9 about here.]

[Figure A.10 about here.]

[Figure A.11 about here.]

[Figure A.12 about here.]

[Figure A.13 about here.]

[Figure A.14 about here.]

[Figure A.15 about here.]

[Figure A.16 about here.]

[Figure A.17 about here.]

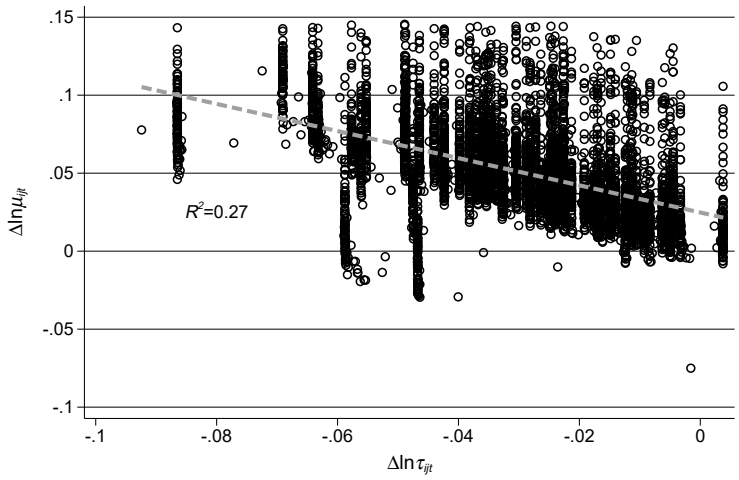


Figure A.1: Year to year percentage changes in τ_{ijt} and μ_{ijt} for 2015 without domestic trade

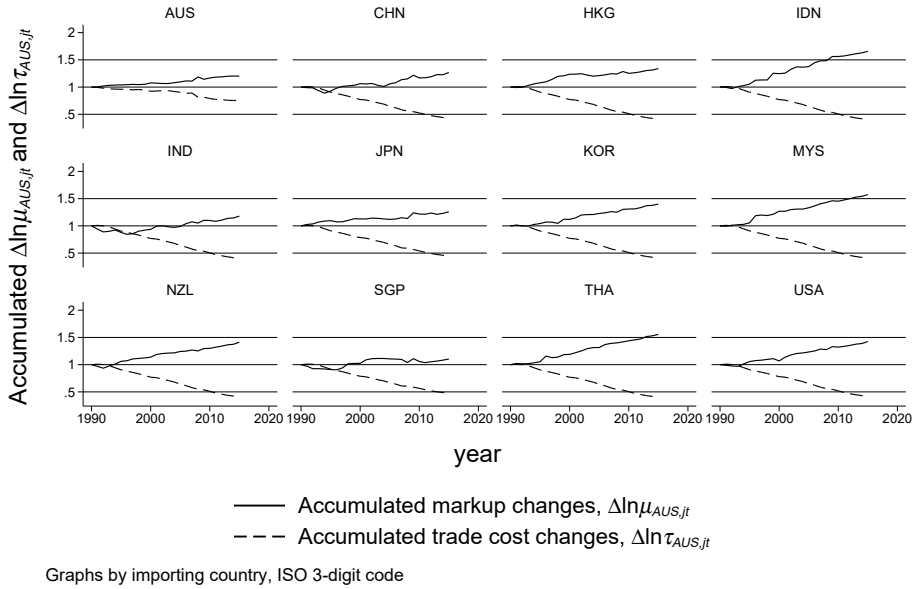


Figure A.2: Accumulated changes in Australia's markups and trade costs in its top 12 sales markets

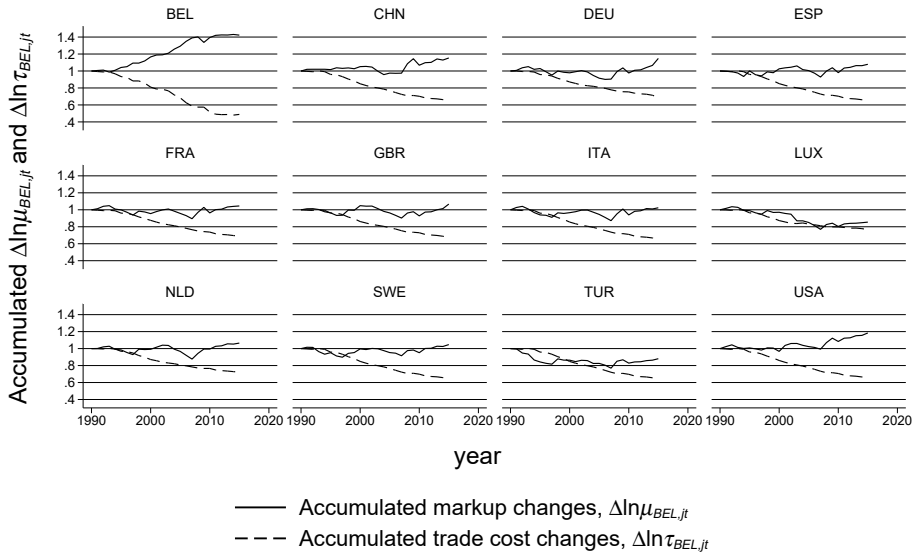


Figure A.3: Accumulated changes in Belgium's markups and trade costs in its top 12 sales markets

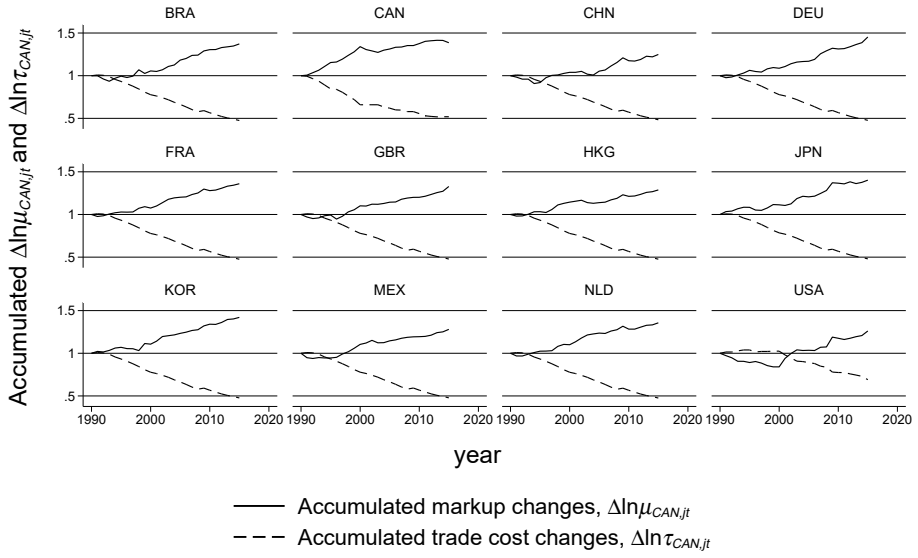


Figure A.4: Accumulated changes in Canada's markups and trade costs in its top 12 sales markets

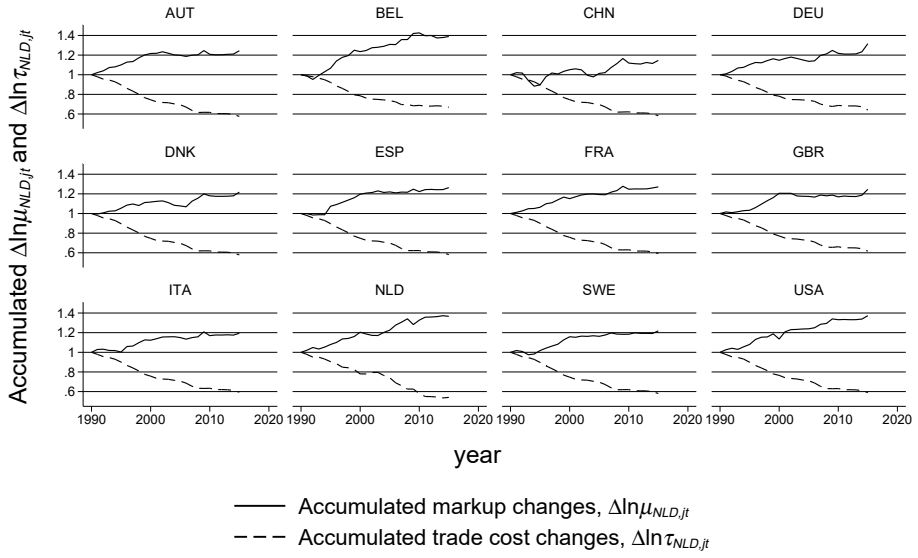


Figure A.5: Accumulated changes in the Netherland's markups and trade costs in its top 12 sales markets

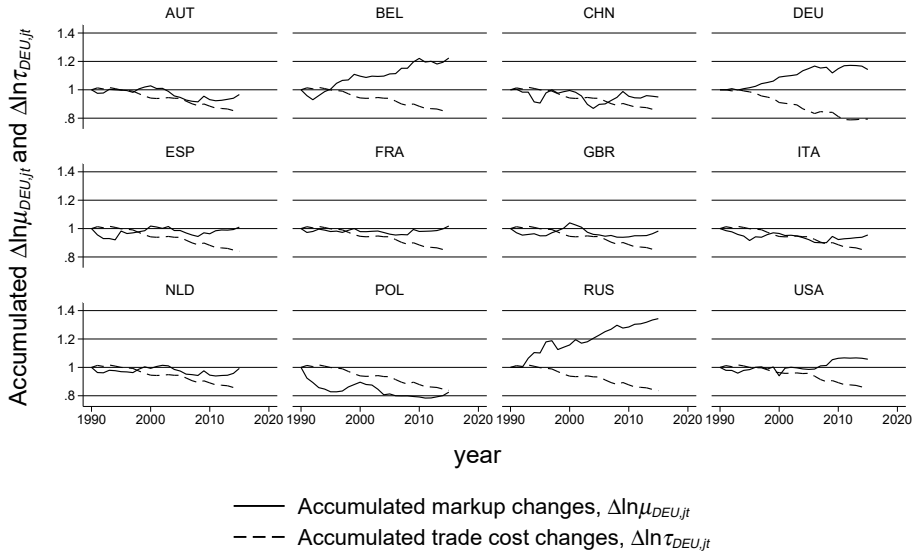


Figure A.6: Accumulated changes in Germany's markups and trade costs in its top 12 sales markets

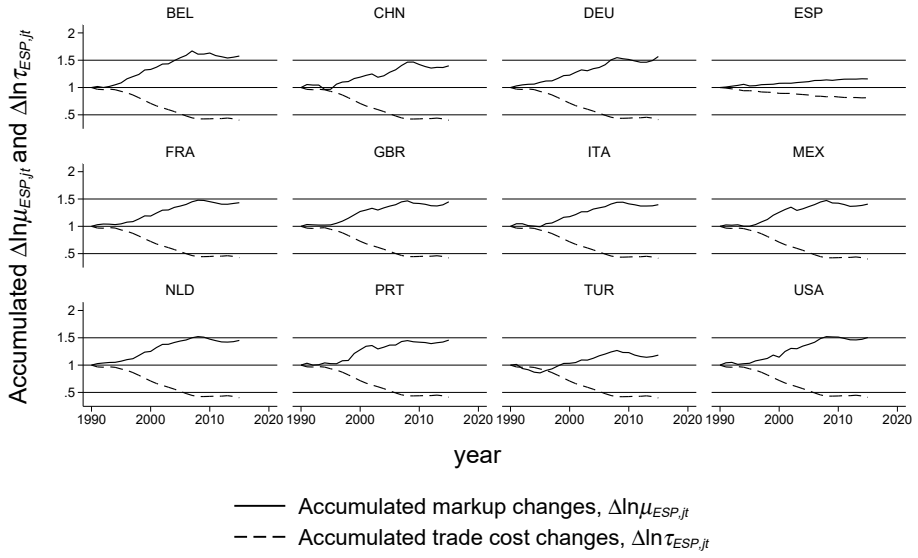


Figure A.7: Accumulated changes in Spain's markups and trade costs in its top 12 sales markets

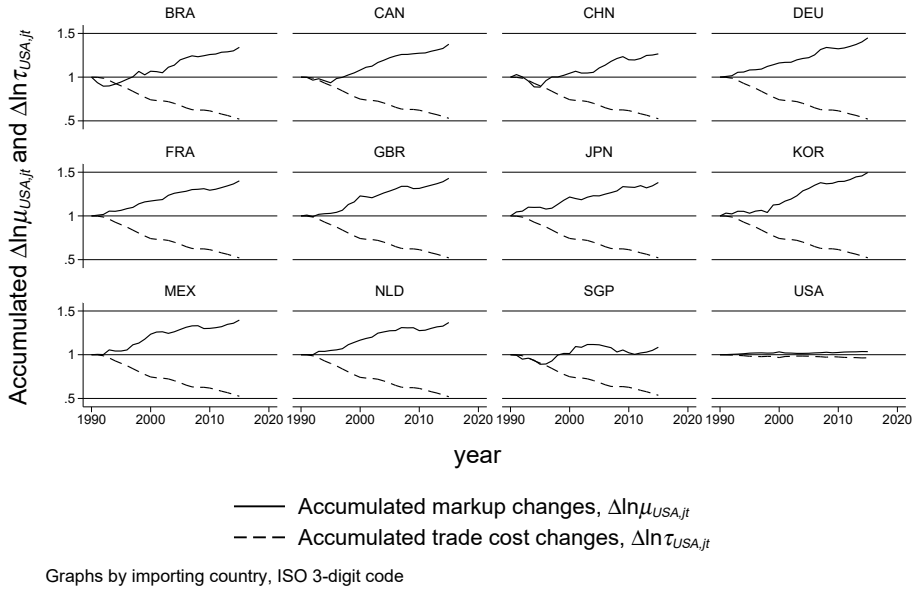


Figure A.8: Accumulated changes in the United States' markups and trade costs in its top 12 sales markets

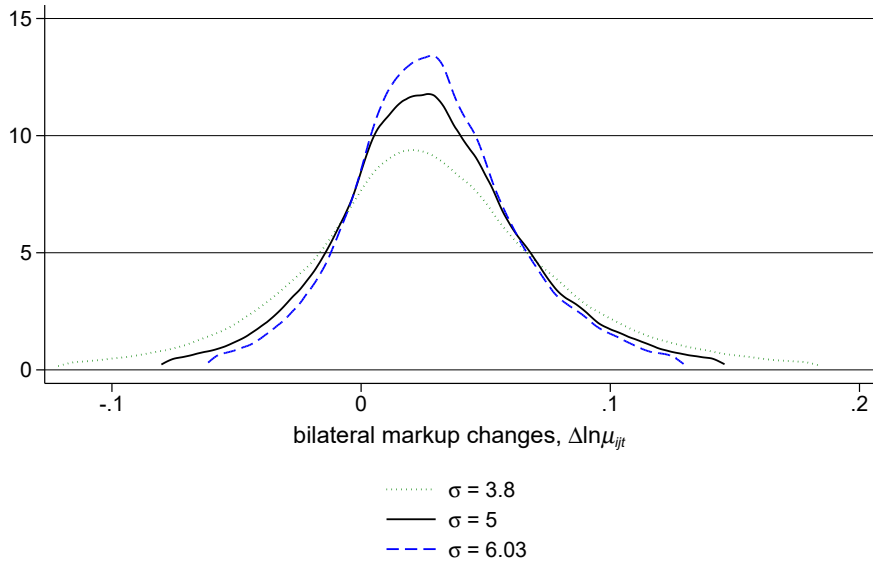


Figure A.9: Kernel density plot of markup changes using different elasticities

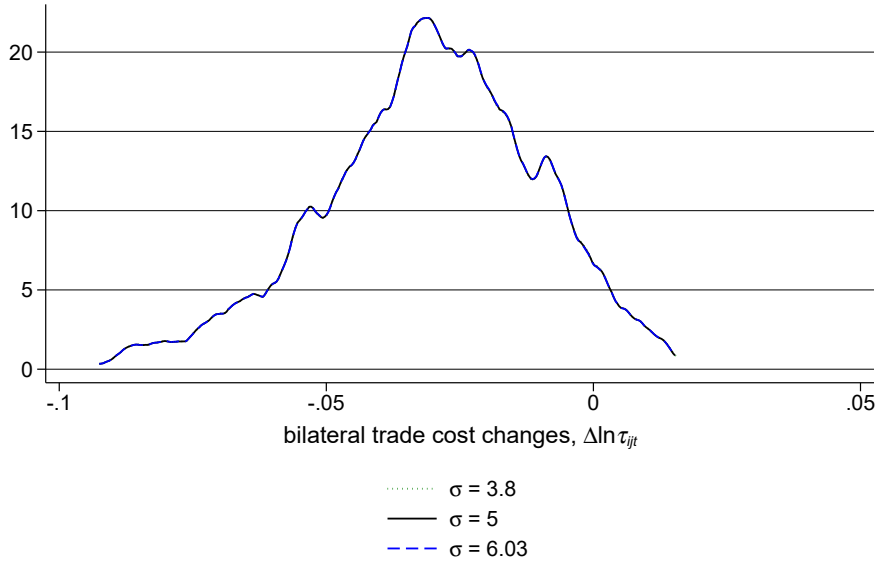


Figure A.10: Kernel density plot of trade cost changes using different elasticities

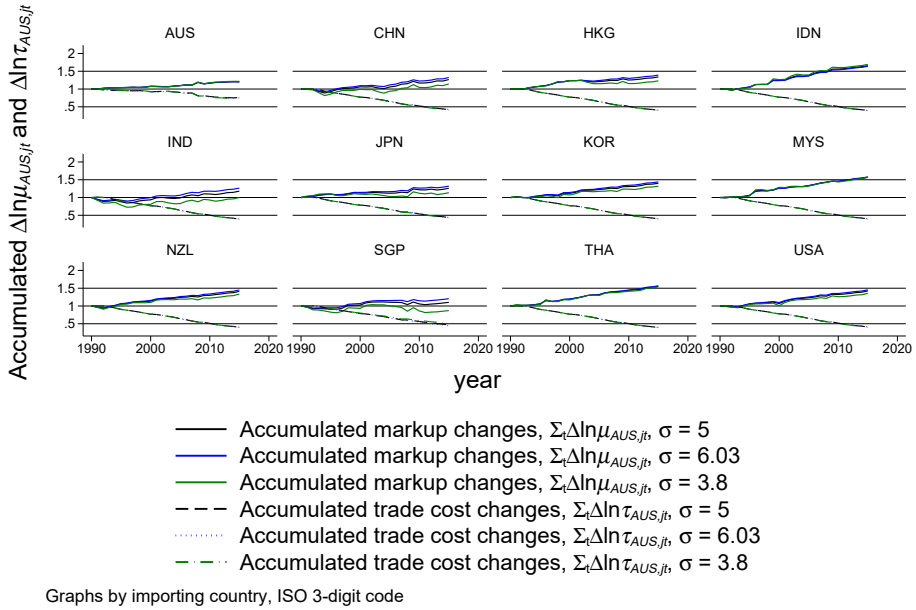


Figure A.11: Accumulated changes in Australia's markups and trade costs in its top 12 sales markets using different elasticities

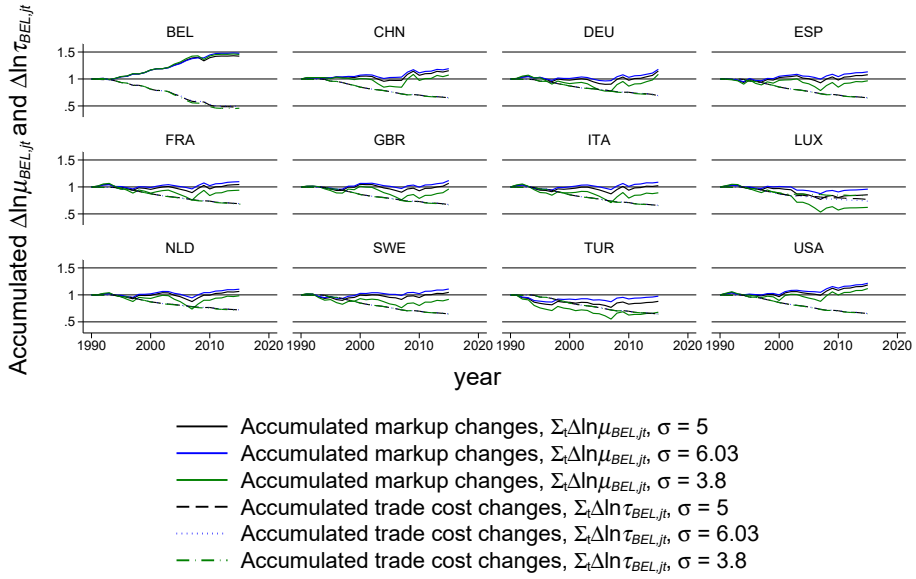


Figure A.12: Accumulated changes in Belgium's markups and trade costs in its top 12 sales markets using different elasticities

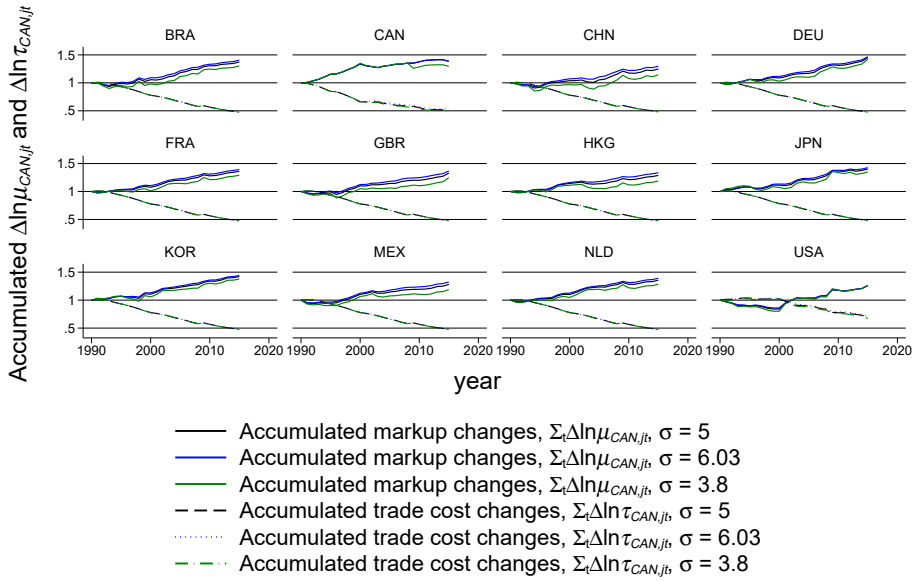


Figure A.13: Accumulated changes in Canada's markups and trade costs in its top 12 sales markets using different elasticities

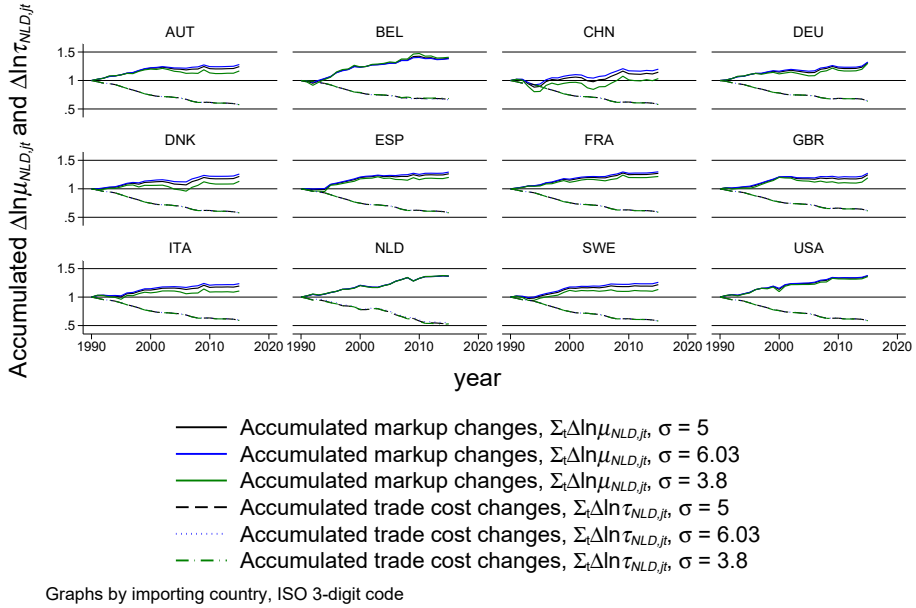


Figure A.14: Accumulated changes in Netherland's markups and trade costs in its top 12 sales markets using different elasticities

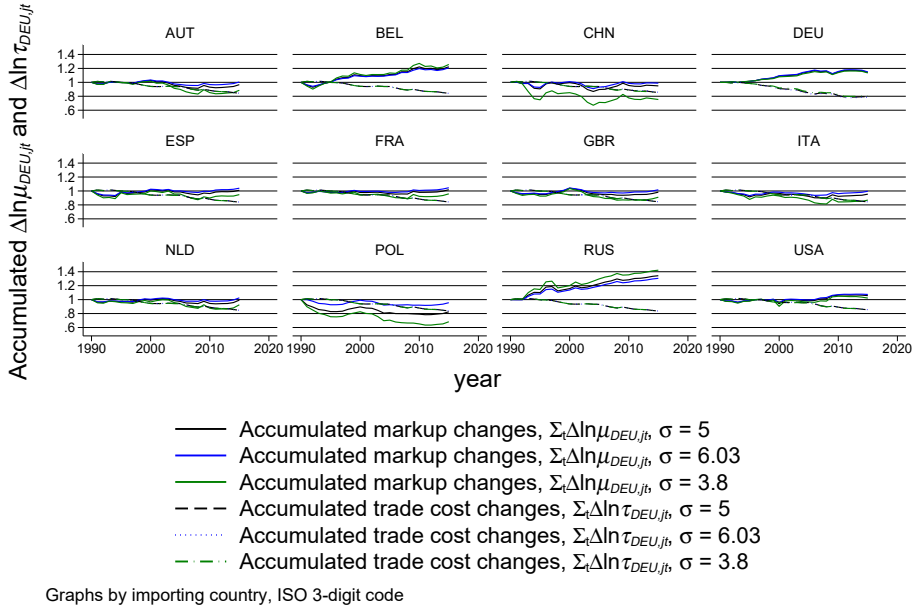


Figure A.15: Accumulated changes in Germany's markups and trade costs in its top 12 sales markets using different elasticities

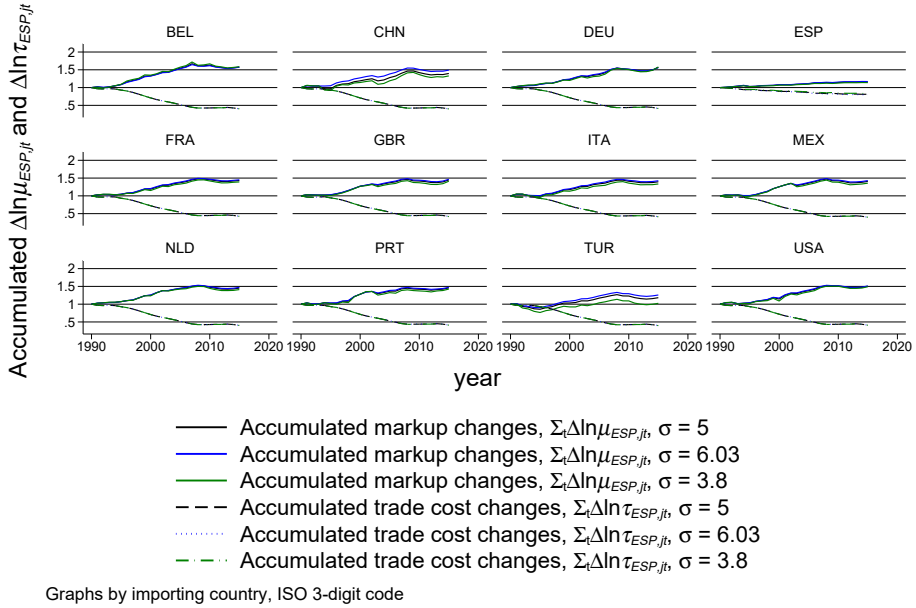


Figure A.16: Accumulated changes in Spain's markups and trade costs in its top 12 sales markets using different elasticities

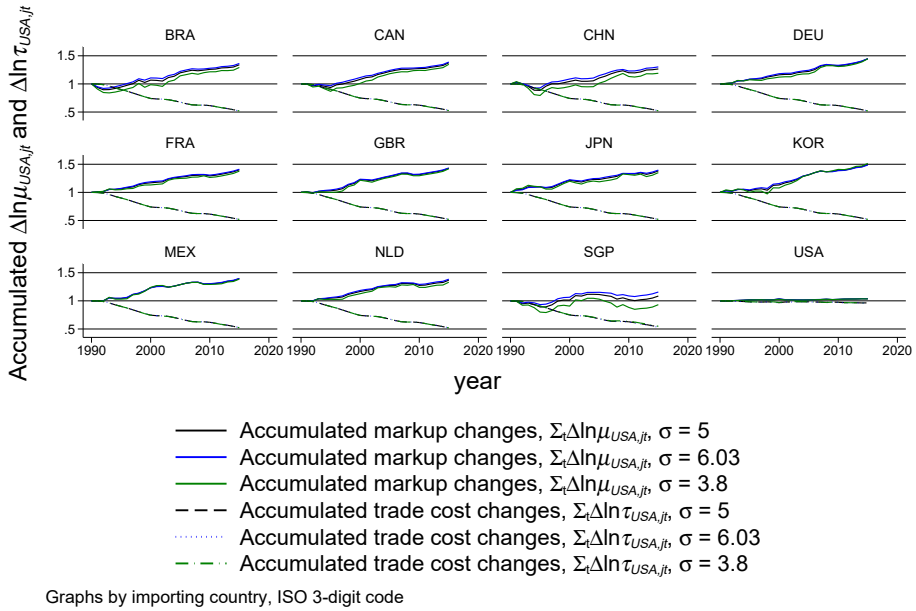


Figure A.17: Accumulated changes in the United States' markups and trade costs in its top 12 sales markets using different elasticities

Table A.1: List of reference country pairs

exporter	importer	V_{ij}	exporter	importer	V_{ij}
KOR	TWN	0.004	NZL	TWN	0.050
OMN	TWN	0.005	VNM	TWN	0.050
JPN	TWN	0.005	BGD	TWN	0.053
KWT	TWN	0.006	CHE	TWN	0.054
IDN	TWN	0.006	GRC	TWN	0.054
CAN	TWN	0.006	BGR	TWN	0.057
FRA	TWN	0.007	CRI	TWN	0.058
HKG	TWN	0.008	SVN	TWN	0.058
JOR	TWN	0.009	PER	TWN	0.060
NLD	TWN	0.010	UKR	TWN	0.061
AUS	TWN	0.010	POL	TWN	0.062
DZA	TWN	0.011	ARG	TWN	0.063
MEX	TWN	0.011	ESP	TWN	0.063
SAU	TWN	0.014	ROU	TWN	0.063
THA	TWN	0.014	LTU	TWN	0.069
DEU	TWN	0.016	GTM	TWN	0.070
CHL	TWN	0.016	EST	TWN	0.072
CUB	TWN	0.016	URY	TWN	0.072
MYS	TWN	0.020	SVK	TWN	0.079
TWN	PHL	0.021	COL	TWN	0.087
FIN	TWN	0.021	SUD	AUS	0.088
ZAF	TWN	0.021	PRT	TWN	0.089
ITA	TWN	0.022	EGY	TWN	0.090
BHR	TWN	0.023	BOL	TWN	0.090
ISR	TWN	0.023	VEN	TWN	0.095
RUS	TWN	0.024	HND	TWN	0.095
TWN	SGP	0.025	TUN	TWN	0.096
DNK	TWN	0.025	SUD	BEL	0.096
IND	TWN	0.026	PRY	TWN	0.105
AGO	TWN	0.026	GHA	TWN	0.109
GBR	TWN	0.026	TTO	TWN	0.110
AUT	TWN	0.027	DOM	SUD	0.113
PAK	TWN	0.027	HRV	TWN	0.118
USA	TWN	0.028	MMR	TWN	0.135
SWE	TWN	0.028	CIV	TWN	0.137
CHN	TWN	0.029	UZB	SUD	0.140
NOR	TWN	0.031	KAZ	TWN	0.150
LKA	TWN	0.032	QAT	TWN	0.151
MAR	TWN	0.034	KEN	SUD	0.154
NGA	TWN	0.035	LBN	SUD	0.166
ARE	TWN	0.036	SYR	SUD	0.179
CZE	TWN	0.036	SUD	COD	0.183
ECU	TWN	0.039	PAN	TWN	0.184
YEM	TWN	0.041	GUY	TWN	0.201
HUN	TWN	0.042	NOR	LUX	0.211
BRA	TWN	0.043	LBY	TWN	0.220
IRN	TWN	0.045	LVA	TWN	0.235
IRL	TWN	0.045	IRL	AZE	0.268
IRQ	TWN	0.045	SRB	ISR	0.917
TUR	TWN	0.049			

Table A.2: Relationship between markup and trade cost changes using the uncorrected Solow residual

dep. var.: $\Delta \ln \mu_{ijt}$	(1)	(2)	(3)	(4)
	1990–2015	2015	1990–2015	2015
	domestic and international trade		only international trade	
$\Delta \ln \tau_{ijt}$	−0.867***	−0.875***	−0.867***	−0.858***
	(0.027)	(0.109)	(0.027)	(0.110)
R^2	0.287	0.407	0.285	0.393
N	165568	6995	163837	6924

Notes: Table reports regression coefficients of regressing the annual log change in bilateral aggregate markups, $\Delta \ln \mu_{ijt}$, on the annual log change in bilateral aggregate trade costs, $\Delta \ln \tau_{ijt}$. All regressions include a constant that is not reported. Cameron et al. (2011) standard errors are robust to multiway clustering across exporters and importers. We use the `reghdfe` command by Correia (2017) in Stata 18.0. ** significant at the 5% level, *** significant at the 1% level.