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 6.8% per year. Since bilateral aggregate trade costs have fallen, we find a strong negative correlation between observed trade cost and markup changes. Finally, our framework allows us to quantify how markups affect the welfare gains from trade liberalization. A conservative estimate is that, on average, welfare gains would be about a third larger if markups had stayed constant.

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

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1 Introduction

All national and international transactions are subject to some sort of frictions like transport, insurance and regulations. A common perception of globalization is that the world has become flat, meaning that international trade has experienced a decline in frictions compared to intranational trade. Furthermore, an easier access to foreign markets and increasing imports may have implied more competition, at least on an aggregate level. At the same time, however, we observe the rise of big firms, in particular in markets in which winners take it all, and this increased market power allows these firms to charge larger markups. The difference between prices and costs gives rise to markup frictions, and their change is a result of the change in the competitive environment in which exporters and importers are operating. 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.

This paper complements two strands of the literature on frictions. One strand of the literature in international trade has developed quantitative trade models, and frictions and their changes have been scrutinized in structural gravity model in particular. Trade economists try to estimate the effects of globalization, 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 have to assume a certain market conduct. The common perception is that even allowing for endogenous markups does not make them important, and that trade cost changes continue to be the important drivers.

The other strand of the literature has dealt with markups using detailed firm-level data. These papers estimate total factor productivity on firm level and markups from a cost minimization approach, and they derive markups either for all sales or for domestic sales versus foreign sales. This literature finds that markups have gone up substantially, contradicting the assumptions of quantitative trade model. For example, De Loecker et al. (2020) find that aggregate global markups have increased from 1.21 in 1980 to 1.61 in 2016. The increase in markups is also well documented in other papers, 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 trade literature typically thinks that markups only play a minor or no role, the IO literature typically abstracts from trade costs and does not specify country-to-country markups.

In this paper, we provide a simple framework that tries to bridge both strands of the literature. To the best of our knowledge, we are the first to provide evidence on markup and trade cost changes on aggregate country-to-country level, using aggregate trade data. Our model relies on minimum assumptions of demand and supply. As for demand, it follows 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 cost-minimizers or profit-maximizers. Under these minimal assumptions, we 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 illustrate our research strategy in Figure 1. The trade flows X_{ijt} from country i to country j in period t determine the bilateral, directional aggregate frictions θ_{ijt}. The quantities sold are then computed by division of trade flows by the respective aggregate friction times the 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 the trade cost changes $d\tau_{ijt}/\tau_{ijt}$. Since we also have the changes in aggregate frictions $d\theta_{ijt}/\theta_{ijt}$, the change in markups $d\mu_{ijt}/\mu_{ijt}$ are the difference between the changes in aggregate frictions and the trade cost changes.

Consequently, the remainder of this paper is organized as follows. Section 2 develops the model which will use to determine aggregate frictions and their changes, and section 3

[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 (2020) and Hsu et al. (2020).

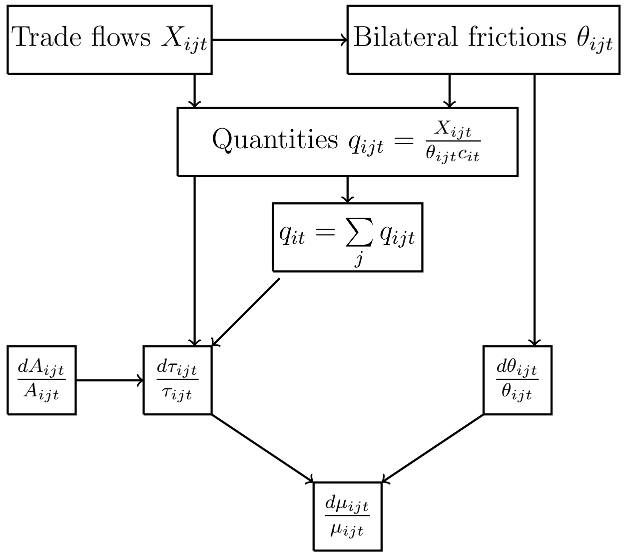

Figure 1: Howto of disentangling frictions

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 some of our results, and section 6 concludes.

2 The model

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 θ_{ij} measures the aggregate frictions of exports from country i to country j. The composite good is sold for a price $p_{ij} = \theta_{ij}c_i$ such that $X_{ij} = p_{ij}q_{ij}$ where c_i denotes country i's f.o.b. unit cost. Aggregate frictions collect two distortions: first, trade frictions, denoted by τ_{ij}, are of the iceberg type and measure the additional cost that has to be carried for exports from country i to country j. Consequently, the c.i.f. cost of serving market j is given by the trade friction times the f.o.b. cost, that is, $\tau_{ij}c_i$. Second, producers in country i may have market power that allows them to charge a markup over the c.i.f. cost such that $\theta_{ij} = \mu_{ij}\tau_{ij}$ where μ_{ij} denotes the markup.

To empirically measure how aggregate bilateral markups and trade costs change over time, we need to identify the change in aggregate frictions for each country pair for each year. At first glance, a gravity equation that uses a parametric trade friction specification seems like a 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 markups i charges in market j are identical to the changes in markups j charges in 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. Finally, Egger and Nigai (2015) demonstrate that standard parametric trade friction functions suffer from omitted variable bias due to unobserved drivers of frictions. Furthermore, we want to identify aggregate frictions to begin with, and it is not obvious what the impact of these typically used variables on markups could be, if there is any at all.[3]

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:

$$X_{ijt} = \exp\left(\eta_{it} + \nu_{jt} + \delta_{ijt}\right), \tag{1}$$

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:

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

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 gravity literature, see Fally (2015), and is v) consistent with standard general equilibrium

[3]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 **?**.

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.[4] This model is – among many others – completely consistent with eq. (1). 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:

$$X_{ijt} = \underbrace{\frac{Y_{it}}{Q_{it}^{1-\sigma} Y}}_{\exp(\eta_{it})} \underbrace{\frac{E_{jt}}{P_{jt}^{1-\sigma}}}_{\exp(\nu_{jt})} \underbrace{\theta_{ijt}^{1-\sigma}}_{\exp(\delta_{ijt})} \tag{2}$$

In (2), $Y_{it}(Y)$ is country i's (world) GDP, 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 good 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.[5]

For each year t in our trade flow data set for n countries, including internal trade, eq. (1) 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. (1) represents an overdetermined 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 Egger and Nigai (2015) and set $\delta_{ii} = 1$. As explained by Egger and Nigai (2015), in total,

[4]This model is derived in detail in Appendix A.1

[5]Computationally, this method can be implemented using STATA's `reg` command, when realizing that (2) 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.

$n^2 - n - 1$ free bilateral friction parameters δ_{ij} can be identified.[6]

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 $\sigma = 5$, close to the preferred estimate of $\sigma = 5.03$ of the literature survey of Head and Mayer (2014).[7] 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 (1) without correction.[8]

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} is a pure trade friction, this implies that any increase or decrease in trade frictions translates one to one into a price change. As mentioned before, we can write the aggregate friction as a product of markups μ_{ij} and trade costs τ_{ij}. In models of perfect and Dixit-Stiglitz monopolistic competition, little or nothing changes:

[6] Hence $n-1$ values of δ_{ij} have to be normalized. Without loss of generality, we choose $n-1$ reference country pairs where $d\delta_{ij} = 0$, i.e., the bilateral aggregate frictions should be interpreted relative to these reference country pairs. Particularly note that this does not imply that frictions are 0 between these country pairs, similar to setting $\delta_{ii} = 1$ does not imply that domestic frictions are zero. Instead, frictions should be interpreted relative to the reference country pairs. Also 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.2. The list of reference country pairs can be found in Table A.1 in Appendix A.2.

[7] $\sigma = 5$ is also close to the estimated value of 4.927 of Gaubert and Itskhoki (2021) and the estimated value of 5.39 of Breinlich et al. (2020). Both papers employ a structural, oligopolistic trade model. We also check robustness and use $\sigma = 3.8$, the median value result of the meta-study by Bajzik et al. (2020), and our results hardly change. Details are available upon request.

[8] 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. The details are available upon request.

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 its changes).

We want to allow that markups may respond to trade cost or other changes in the competitive environment, and this is the reason why we have employed a generalized gravity model that can accommodate both frictions in section 2. Suppose that we have obtained the aggregate frictions $\theta_{ij} = \mu_{ij}\tau_{ij}$ (and their changes) from the methodology outlined in section 2. As we do not want to rely on the assumption of zero or constant markups, we now want to distinguish between markup frictions μ_{ij} and trade frictions τ_{ij} (and their changes) from the data we observe. In order to do so, we have to transform trade values into output. We measure output using the normalized unit cost $\theta_{ii}c_i = c_i$ as a numeraire such that $q_{ij} = X_{ii}/(\theta_{ij}c_i)$ implying $q_{ii} = X_{ii}$ which we will use for disentangling μ_{ij} and τ_{ij}. From our θ_{ij}-estimates and the observed trade flows, we can then also determine aggregate production $q_i = \sum_j q_{ij}$.

As for production, we do not make any assumption on market structures and firm behavior except that each economy does not waste resources but operates on its production function. In particular, each country chooses inputs z_i where z_i is the vector of k factors of production which 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. We now want to use the variation in destination-specific marginal costs to be able to disentangle trade and markup frictions. For this purpose, we 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

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

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

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

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

$$\widetilde{d}C_{ij} = d\tau_{ij} \sum_k w_{ik} z_{ik} + \tau_{ij} \sum_k w_{ik} dz_{ik}, \tag{3}$$

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

$$\widetilde{d}q_{ij} = dq_{ij} - q_{ij} \frac{dA_i}{A_i}. \tag{4}$$

The marginal cost for serving market j is given by $\widetilde{d}C_{ij}/\widetilde{d}q_{ij}$ (and equal to the unit cost c_i times the trade friction τ_{ij}), and consequently the destination-specific markup is given by

$$\mu_{ij} = \frac{p_{ij}}{\widetilde{d}C_{ij}/\widetilde{d}q_{ij}} \Leftrightarrow \mu_{ij} \widetilde{d}C_{ij} = p_{ij} \widetilde{d}q_{ij}. \tag{5}$$

Using (3) and (4) in (5) yields

$$\mu_{ij} \left[d\tau_{ij} \sum_k w_{ik} z_{ik} + \tau_{ij} \sum_k w_{ik} dz_{ik} \right] = p_{ij} \left[dq_{ij} - q_{ij} d \ln A_i \right]. \tag{6}$$

Since $\sum_k w_{ik} z_{ik} = c_i q_i$ and $p_{ij} q_{ij} = \theta_{ij} c_i q_{ij}$, we can rewrite (6) and solve for the change in trade frictions such that

$$d \ln \tau_{ij} = \frac{q_{ij}}{q_i} \left[d \ln q_i - d \ln A_i \right] - \sum_k \alpha_{ik} d \ln z_{ik}, \tag{7}$$

where $\alpha_{ik} = w_{ik} z_{ik} / c_i q_i$ is the cost share of the factor of production k in country i. We assume a Cobb-Douglas production function such that $\ln q_i = \ln A_i + \sum_k \alpha_{ik} \ln z_{ik}$, so total differentiation implies $d \ln q_i = d \ln A_i + \sum_k \alpha_{ik} d \ln z_{ik}$, and thus

$$d \ln \tau_{ij} = \frac{q_{ij} - q_i}{q_i} \left[d \ln q_i - d \ln A_i \right]. \tag{8}$$

The unit cost c_i will change over time. Since $X_{ij} = \theta_{ij} c_i q_{ij}$, implying $q_{ij} = X_{ij}/(\theta_{ij} c_i)$, we can write aggregate production in log form as

$$\ln q_i = \ln \left[\sum_j \left(\frac{X_{ij}}{\theta_{ij}} \right) \right] - \ln c_i$$

which allows us to rewrite (8) as

$$d \ln \tau_{ij} = \frac{\frac{X_{ij}}{\theta_{ij}} - \sum_j \left(\frac{X_{ij}}{\theta_{ij}} \right)}{\sum_j \left(\frac{X_{ij}}{\theta_{ij}} \right)} \left[d \ln \left[\sum_j \left(\frac{X_{ij}}{\theta_{ij}} \right) \right] - d \ln c_i - d \ln A_i \right]. \tag{9}$$

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

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

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

$$d \ln Y_i = d \ln c_i + d \ln Y_i^r \Leftrightarrow d \ln c_i = d \ln Y_i - d \ln Y_i^r = d \ln \sum_j X_{ij} - d \ln Y_i^r. \tag{10}$$

We can then finally derive the change in markup frictions as

$$d \ln \mu_{ij} = d \ln \theta_{ij} - d \ln \tau_{ij}. \tag{11}$$

Thus, equations (9) and (11) allow us to disentangle the change of aggregate frictions into trade and market power friction changes for all source and destination countries. Furthermore, we can complement our analysis by a welfare analysis if we are willing to make further assumptions on demand. In Appendix A.4, we generalize the welfare formula of Arkolakis et al. (2012) and we show that welfare changes for a country can be given by

$$\widehat{W}_j = \widehat{E}_j \widehat{\Lambda}_j^{\frac{1}{1-\sigma}} = \frac{\widehat{E}_j \widehat{\lambda}_{jj}^{\frac{1}{1-\sigma}}}{\widehat{c}_j \widehat{\theta}_{jj}}. \tag{12}$$

Eq. (12) shows that – as in Arkolakis et al. (2012) – the welfare change can be computed by domestic changes only: it depends positively on the change in income, measured by 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.

As a counterfactual, we assume that the change in markups is zero while $\widehat{E}_j, \widehat{\lambda}_{jj}$ and $\widehat{c}_j$ do not change. We thus 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

$$\widehat{W}_j^* = \widehat{W}_j \widehat{\mu}_{jj}. \tag{13}$$

Eq. (13) 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 will allow us to infer how taking into account markup changes affects the welfare effects of trade cost changes observed in the data. Of course, in a general equilibrium model like ours, 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, (13) is a lower bound in this context. Having described our model, we bring it to the data in the next section.

4 Empirical results

4.1 Baseline

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).[9] 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.[10] To measure the change in unit costs, $d\ln c_i$ in eq. (9), we use TO BE ADDED. To measure the change in TFP, $d\ln A_i$ in eq. (9), we use the Penn World Tables 10.0 (PWT) by Feenstra et al. (2015). We use the TFP measure at current PPPs (variable "ctfp").[11] Using these data, we decompose aggregate frictions for all exporter-importer pair using eq. (8), including domestic trade for the 71 countries for which we have both data in Eora26 and in the PWT.

First, we illustrate how year-to-year markup and trade cost changes are distributed. Figure 2 shows the density plot of all year-to-year markup changes.[12] We find that markup changes have been positive on average with a mean of 7.0% and a median of 6.3%. Figure 2 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 3 shows the density plot of all year-to-year trade cost changes. Consistent with the findings in the trade literature, we find that bilateral trade costs have fallen on average. But this does not hold true in general as we also see some bilateral trade cost increases.

Figure 2 and Figure 3 about here.

This immediately raises the question how markup and trade cost changes are correlated. Figure 4 shows for the year 2015 that we indeed find a strong negative correlation between markup and trade cost changes. While this observation does not establish any causality,

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

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

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

[12]For ease of graphical depiction, we trim the data at the 2% and 98% percentile in both Figure 2 and Figure 3, similar to De Loecker and Eeckhout (2021).

it shows that at least parts of trade liberalization gains may have been compensated by markup increases. Figure 5 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 identify gains from trade, and this implies that the reduction in trade costs dominates the increase in markups. Thus, we also observe a decrease in aggregate frictions in our data.

Figure 4 and Figure 5 about here.

Our analysis provides us with year-to-year bilateral markup and trade cost changes, Taking these data, we can sum them up by 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 Figure 6. Cleary, average sales markups have gone up everywhere except Taiwan, where they have fallen by 2%. We observe the largest increase of markups in China, where markups are 4.7 times larger than in 1990. In general, developed economies have seen smaller increases in markups compared to developing and middle-income countries.

Figure 6 about here.

Importantly, our method also allows us to quantify the 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 sales markups for Belgium, the Netherlands, Germany, and the United States for their largest 12 sales markets (including their domestic market) in Figures 8, 10, and 11 from 1990 to 2015, where we set the level of markups in 1990 to 1. We see that markups Belgium, the Netherlands, Germany, and the United States charge have increased across all markets with the exception of the markups Belgium charges in Russia. Markups have increased the most in China for all three considered exporters. We also find that domestic markups have changed relatively little in comparison with markups in the export markets.

Figure 8, Figure 9, Figure 10, and Figure 11 about here.

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 7 shows the accumulated change in domestic markups from 1990 to 2015. Obviously, there is quite some variation across countries. However, Figure 7 shows that – on average –welfare gains would be 33 % larger if markups had not increased. Since the median is lower and at 27%, we observe that most differential effects are not too large.

Figure 7 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 deadweight losses will reduce aggregate expenses. Furthermore, more competition should imply a decline in the expenditure share of domestically produced goods. Thus, Figure 7 should give us a lower bound.

5 Robustness checks

5.1 TFP measurement under imperfect competition

The TFP measure we use in our baseline results to measure the change in productivity, $d \ln A_i$, is from the Penn World Tables. This TFP measure is derived under the assumption of perfect competition, so while widely used in practice, it is at odds with our model. As a robustness check, we apply a correction to the PWT TFP measure that is consistent with our model framework.

In our baseline specification, we use the change in TFP as measured by the PWT. To construct this measure, the PWT use a Törnqvist index that relates real GDP to technology and production factors to second order approximate any linear-homogenous production function, $Y^r_{i,t} = B_{i,t} f_{i,t}(\mathbf{z}_{i,t})$, where $\mathbf{z}_{i,t}$ is a vector of production factors, labor and capital.[13] TFP is then measured as the increase in real GDP that cannot be accounted for by factor accumulation, i.e.,

$$d \ln B_{i,t} = d \ln Y^r_{i,t} - \sum_k \alpha_{ik,t} d \ln z_{ik,t}. \tag{14}$$

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

However, this is only true under perfect competition or constant markups. Production in our model is given by

$$\ln q_{i,t} = \ln A_{i,t} + \sum_k \alpha_{ik,t} \ln z_{ik,t}.$$

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

$$d \ln A_{i,t} = d \ln q_{i,t} - \sum_k \alpha_{ik,t} d \ln z_{ik,t}. \tag{15}$$

Subtracting (14) from (15) yields

$$d \ln A_{i,t} = d \ln B_{i,t} + d \ln q_{i,t} - d \ln Y_{i,t}.$$

The Solow residual $d \ln B_{i,t}$ and the real GDP growth $d \ln Y_{i,t}$ are provided by the PWT, and our model provides the real output change $d \ln q_{i,t}$, so we can compute the true TFP change $d \ln A_{i,t}$.

5.2 Changes in internal trade frictions

Over time, not only international trade frictions may have changed but also domestic trade frictions. Our framework allows us to back out these domestic changes by using the estimated importer fixed effects $\nu_{j,t}$ from (1).

Replace (17) by

$$c_{i,0}^{1-\sigma} \sum_{j=1}^{n} \theta_{ij,0}^{1-\sigma} \underbrace{\frac{E_{j,0}}{P_{j,0}^{1-\sigma}}}_{\exp(\nu_{j,0})} = Y_{i,0} \Leftrightarrow c_{i,0}^{1-\sigma} \sum_{j=1}^{n} \theta_{ij,0}^{1-\sigma} \exp(\nu_{j,0}) = Y_{i,0} \tag{16}$$

to determine $c_{i,0}$ and replace (**??**) by

$$c_{i,t}^{1-\sigma} \theta_{ii,t}^{1-\sigma} \sum_{j=1}^{n} \tilde{\theta}_{ij,t}^{1-\sigma} \exp(\nu_{j,t}) = Y_{i,t}. \tag{17}$$

to determine $\theta_{ii,t}$.

Note that this equation collapses to the standard scaled prices equation (see page 141 in Anderson (2011)) for perfect competition ($p_{i,t} = c_{i,t}$) and $\theta_{iit} = \tau_{iit} = 1 \quad \forall \quad t$.

We can then take logs and take the total differential (17) to receive

$$(1-\sigma) d \ln c_{i,t} + (1-\sigma) d \ln \theta_{ii,t} + d \ln \left[\sum_{j=1}^{n} \tilde{\theta}_{ij,t}^{1-\sigma} \exp(\nu_{j,t}) \right] = d \ln Y_{i,t}. \tag{18}$$

This can be rearranged to determine $d \ln \theta_{ii,t}$. This equation makes clear that a reduction in domestic trade costs or unit costs acts in an observationally equivalent way.

We can rearrange (18) and solve for $d \ln \theta_{ii,t}$, the change of domestic frictions over time, using the same σ we use to calculate $\tilde{\theta}_{ij,t}$, the data on the change in unit costs $c_{i,t}$ as discussed below, the estimated fixed effects ($\nu_{j,t}$) and data on aggregate sales $Y_{i,t}$.

6 Concluding remarks

This paper has developed a structural model which allows us to disentangle aggregate trade and markup frictions using aggregate trade data. Our specification has minimum requirements for supply and employs a generic structural gravity model to compute aggregate trade frictions. We then apply this method to identify all multilateral resistance terms and bilateral 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 also find that markups have increased; on average the increase was 6.8% per year. Quantitative trade models find a decline in aggregate frictions, and we also find this in our data. Therefore – on average – trade costs have decreased more than markups. But this observation also indicates that any gain from globalization could have been larger if markup increases would not have partially compensated for the decline in trade frictions. Still, we also observe a lot of variation and heterogeneity across exporters and importers.

Our paper has deliberately employed a model that is as general as possible. In this sense, we were able to study the effects of globalization by distinguishing between frictions that arise due to distance, border effects and red tape, and frictions that arise due to market power. Our model has been completely agnostic towards market structures and market conduct, so we see our contribution in providing a detailed country-to-county "forensic accounting" of the effects of international trade over 25 years. We have not explored what has driven this increase in markups. For that, we would need a more specific imperfect competition model that can explain the increase in markups. Our generic structural gravity model can be extended to the sectoral level and can be combined with more specific firm behavior models like in Heid and Stähler (2020). We leave this extension to future research.

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Appendix

A.1 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 from the previous section holds true in any model that arrives at an aggregate gravity equation (see Allen et al. (2020) for the generality and universality of gravity).

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, $\sigma, \sigma > 1$, denotes the elasticity of substitution. Note that q_{jj} is country j's internal 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. In any case, the representative consumer takes prices as given, and utility maximization of (A.1) implies demands

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

where

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

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

$$X_{ij} = c_i \theta_{ij} q_{ij}^{*} = \left(\frac{c_i \theta_{ij}}{P_j} \right)^{1-\sigma} E_j, \tag{A.3}$$

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,

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

which can be rewritten as

$$\begin{aligned} c_i^{1-\sigma} &= \frac{Y_i}{\sum_{j=1}^{n} \left(\frac{\theta_{ij}}{P_j} \right)^{1-\sigma} E_j} = \frac{\frac{Y_i}{Y}}{\sum_{j=1}^{n} \left(\frac{\theta_{ij}}{P_j} \right)^{1-\sigma} \frac{E_j}{Y}} \\ &= \frac{Y_i / Y}{Q_i^{1-\sigma}} \text{ where } Q_i = \left[\sum_{j=1}^{n} \left(\frac{\theta_{ij}}{P_j} \right)^{1-\sigma} \frac{E_j}{Y} \right]^{\frac{1}{1-\sigma}} \end{aligned}$$

is the outward resistance term and $Y = \sum_{j=1}^{n} Y_j$ are the aggregate sales in the world. Replacing $c_i^{1-\sigma}$ in (A.3) yields the gravity equation as

$$X_{ij} = \frac{Y_i E_j}{Y} \left(\frac{\theta_{ij}}{Q_i P_j} \right)^{1-\sigma}. \tag{A.4}$$

A.2 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.

A.3 Cost minimization with Cobb-Douglas

Consider the Cobb-Douglas production function

$$q_i = A_i \prod_k z_{ik}^{\alpha_{ik}},$$

where $\sum_k \alpha_{ik} = 1$. The representative firm minimizes $C_i = \sum_k w_{ik} z_{ik}$ s.t. $q_i \geq \bar{q}_i$ which implies

$$\lambda_i \frac{\partial q_i}{\partial z_{in}} = \lambda_i A_i \prod_k z_{ik}^{\alpha_{ik}} \frac{\alpha_{in}}{z_{in}} = \lambda_i q_i \frac{\alpha_{in}}{z_{in}} = w_{in}$$

for each factor of production n where λ_i denotes the shadow price of the production possibility constraint. We can re-write the first-order condition as $w_{in} z_{in} = \lambda_i q_i \alpha_{in}$, and aggregation implies

$$C_i = \sum_k w_{ik} z_{ik} = \lambda_i q_i \sum_k \alpha_{in} = \lambda_i q_i,$$

such that $\lambda_i = C_i/q_i$ and $z_{in} = \alpha_{in} C_i / w_{in}$ which implies

$$q_i = A_i \prod_k \left(\frac{\alpha_{ik} C_i}{w_{ik}} \right)^{\alpha_{ik}} = A_i C_i \prod_k \left(\frac{\alpha_{ik} C_i}{w_{ik}} \right)^{\alpha_{ik}}.$$

The unit cost $c_i = C_i/q_i$ is thus given by

$$c_i = \frac{1}{A_i} \prod_k \left(\frac{w_{ik}}{\alpha_{ik}} \right)^{\alpha_{ik}}.$$

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			

A.4 Welfare analysis

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

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

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

$$\begin{aligned} d\ln\lambda_{ij} - d\ln\lambda_{jj} &= (1-\sigma)\left[d\ln c_i + d\ln\theta_{ij} - d\ln c_j - d\ln\theta_{jj}\right] \Leftrightarrow \\ d\ln c_i + d\ln\theta_{ij} &= \frac{d\ln\lambda_{ij} - d\ln\lambda_{jj}}{1-\sigma} + d\ln c_j + d\ln\theta_{jj}. \end{aligned}$$

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

$$d\ln P_j = \sum_{i=1}^{n} \lambda_{ij}\left(d\ln c_i + d\ln\theta_{ij}\right) = \frac{d\ln\lambda_{jj}}{\sigma-1} + d\ln c_j + d\ln\theta_{jj} \tag{A.5}$$

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 (A.5) as a differential equation which we can solve for the welfare change

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

A.5 Figures

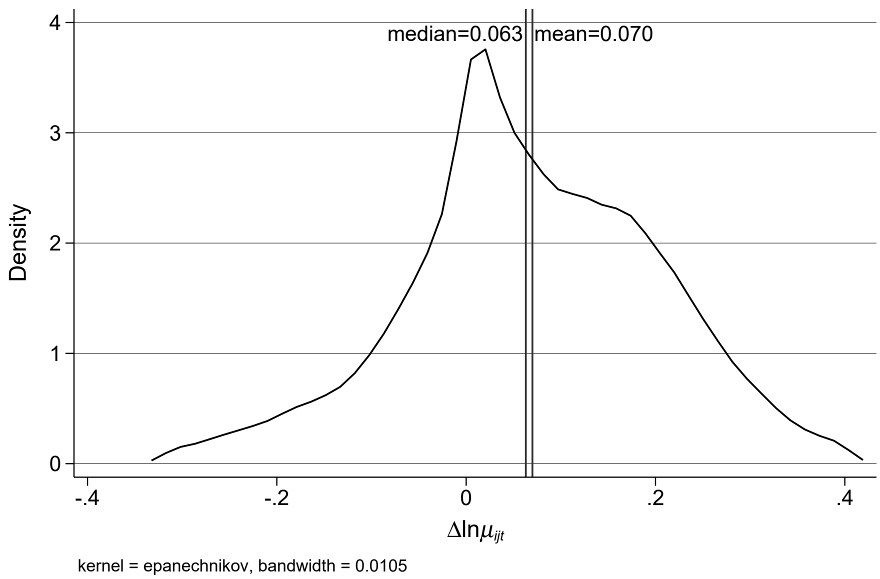

Figure 2: Kernel density plot of all markup changes

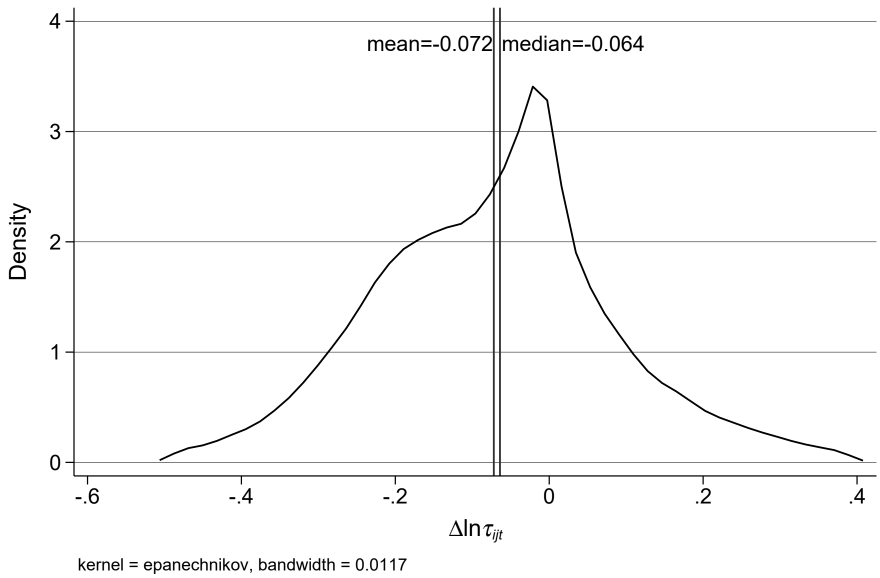

Figure 3: Kernel density plot of all trade cost changes

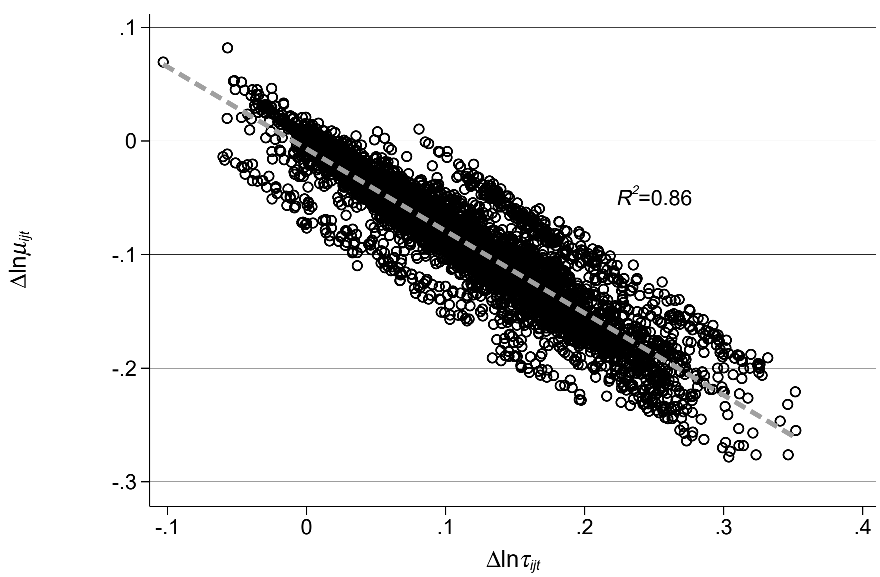

Figure 4: Year to year percentage changes in τ and μ for 2015

Table A.2: 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	
$\Delta \ln \tau_{ijt}$	−0.867***	−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 17.0. ** significant at the 5% level, *** significant at the 1% level.

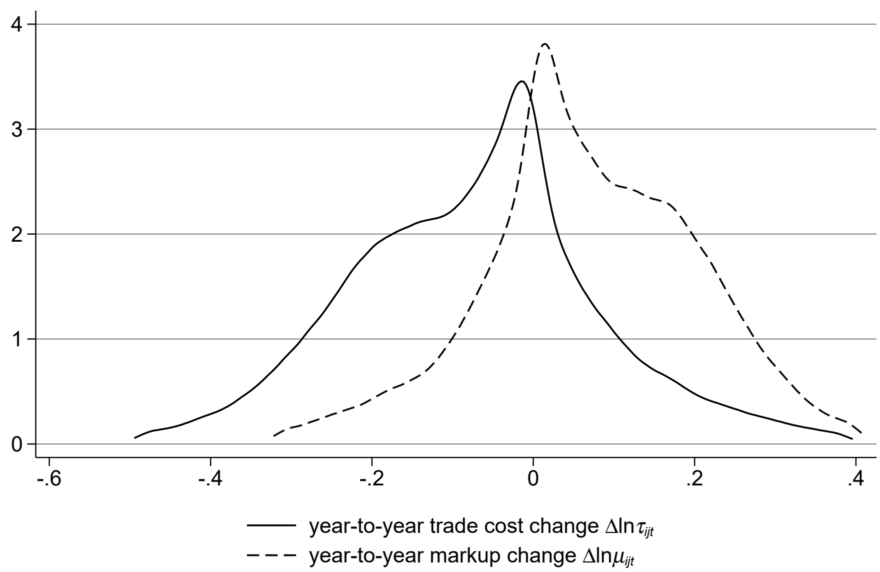

Figure 5: Distribution of year-to-year changes of bilateral trade cost and markup changes

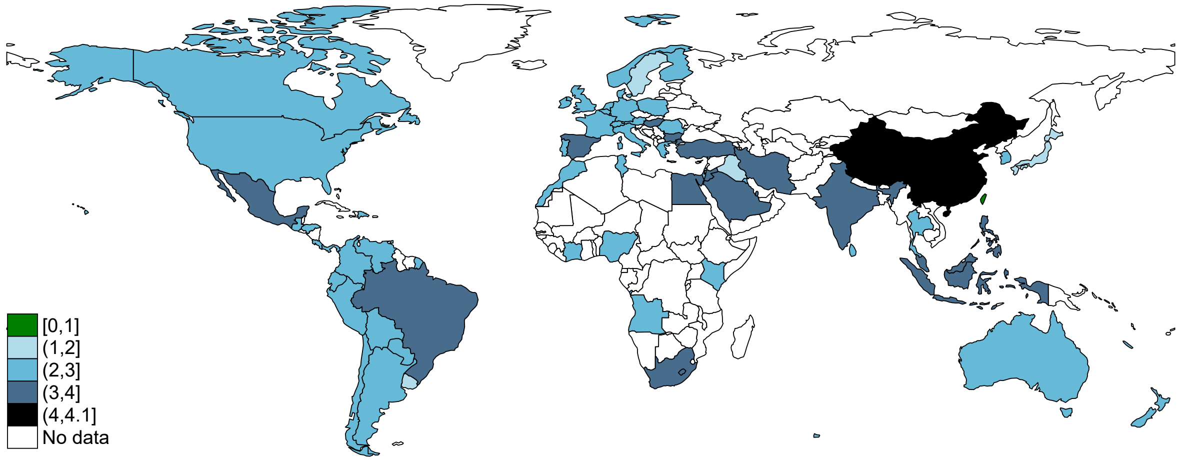

Figure 6: World map of accumulated average sales markup changes from 1990 to 2015, 1990=1

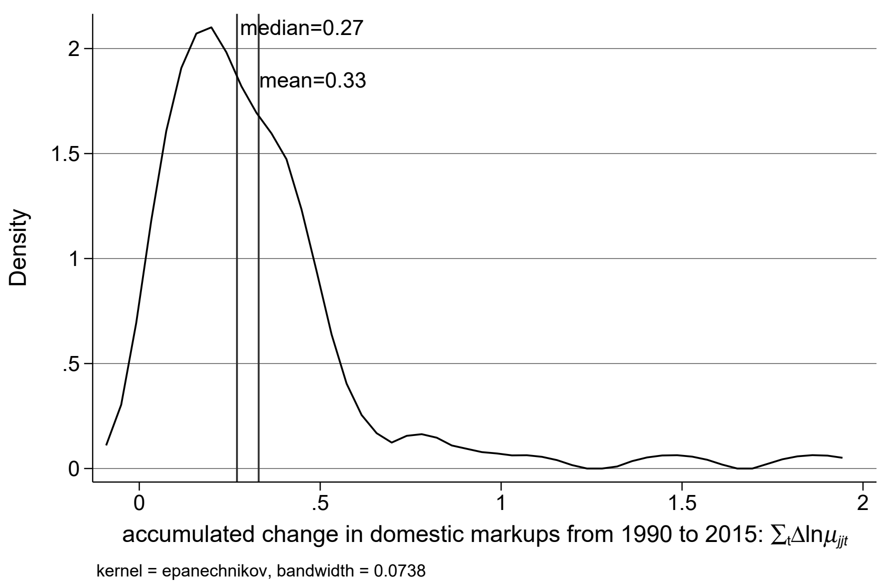

Figure 7: Distribution of accumulated domestic markup changes

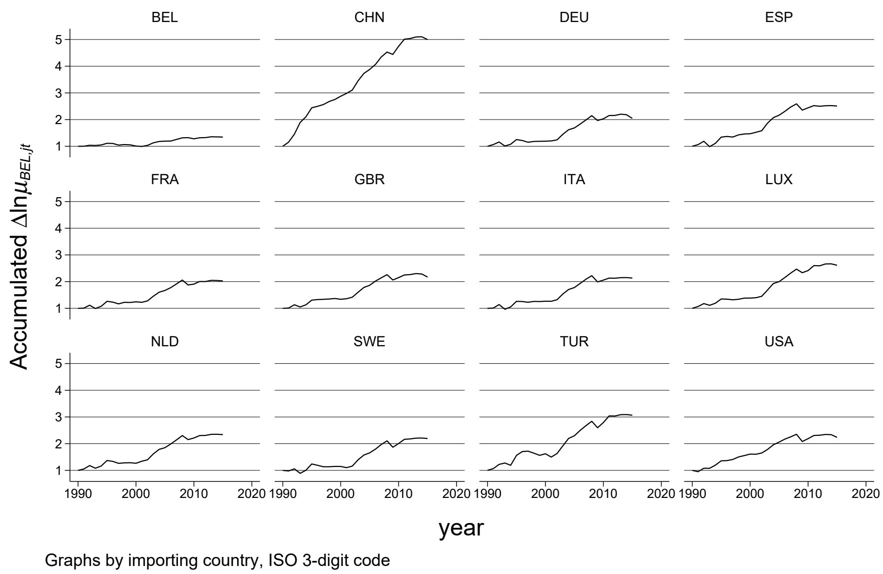

Figure 8: Accumulated changes in Belgium's markups in its top 12 sales markets

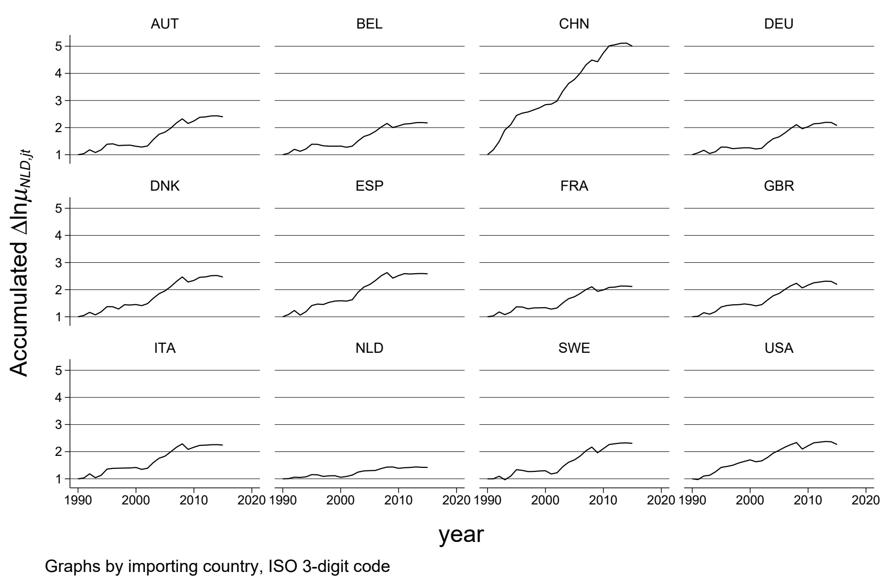

Figure 9: Accumulated changes in Netherland's markups in its top 12 sales markets

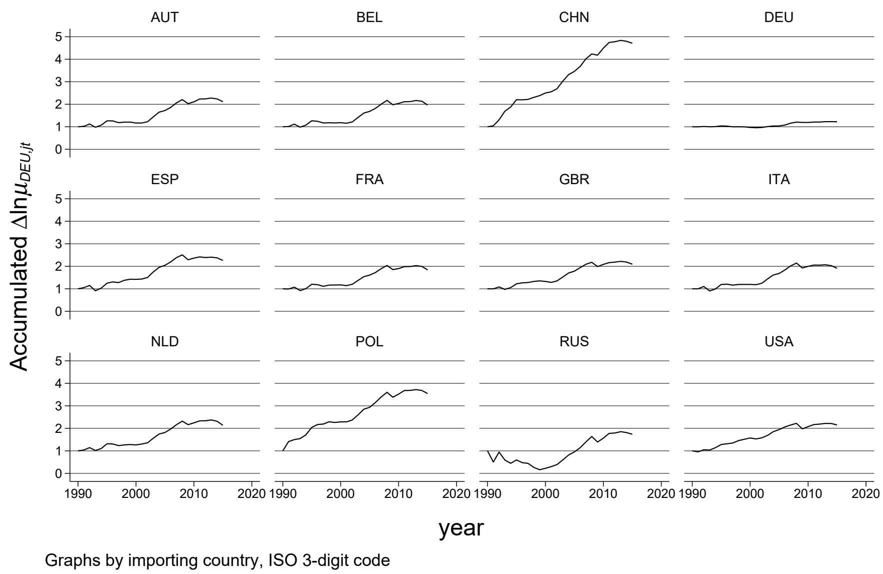

Figure 10: Accumulated changes in Germany's markups in its top 12 sales markets

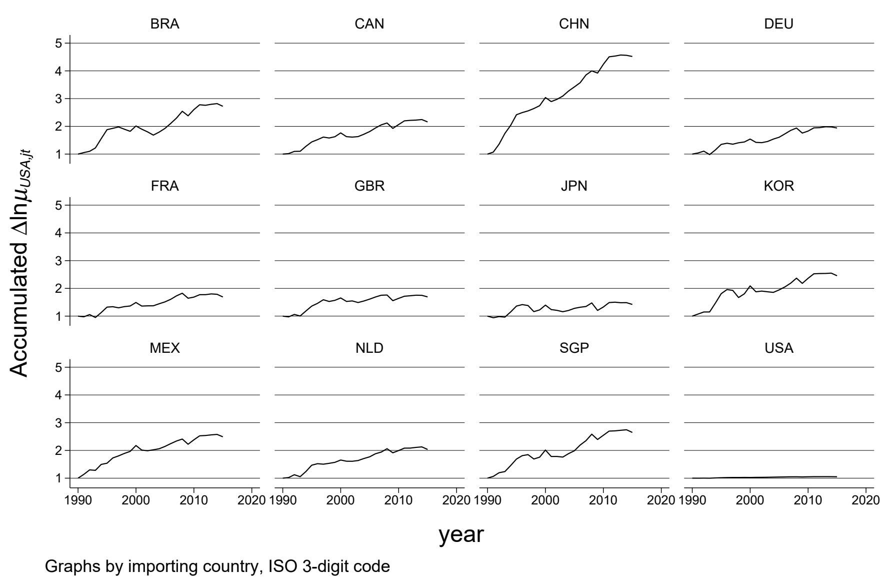

Figure 11: Accumulated changes in the United States' markups in its top 12 sales markets