Markup Heterogeneity, Openness, and the Pro-Competitive Gains from Trade Across Countries*

Hamid Firooz — University of Rochester

Gunnar Heins — University of Florida

Sankalp Mathur — CAFRAL, Reserve Bank of India

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Abstract

How does trade affect global competition and how do pro-competitive gains from trade vary across countries? To answer these questions, we develop a multi-country, multi-sector model of international trade with endogenously determined markups in the presence of (i) sector- and country-specific demand elasticities, (ii) responsiveness of import and export markups to the extent of competition, and (iii) rich variation in market shares, productivity distributions, and trade costs. We quantify the relative importance of each of these factors and document significant cross-country variation in the pro-competitive gains that inversely depend on countries' import shares and the responsiveness of markups to market shares on imports versus exports. Our results suggest that only large countries experience sizable pro-competitive gains from trade and only in the presence of a meaningful degree of variation in demand elasticities. Lastly, we find that the pro-competitive gains from trade are highly sensitive to sectoral variation in tariffs.

JEL Codes: F12, F14.

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*Email: hfirooz@ur.rochester.edu, gheins@ufl.edu, sankalp.mathur@cafral.org.in.

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1 Introduction

One of the classic arguments in favor of international trade is the fostering of competition. Especially in sectors that are dominated by few firms and in which market power is potentially important, proponents of free trade agreements often argue that trade provides great benefits to consumers through reductions in markups and a more efficient allocation of resources. Further, given increasingly more evidence that market power across the world is becoming growingly more relevant (De Loecker and Eeckhout, 2018; De Loecker, Eeckhout and Unger, 2020), such issues are likely to be of even greater importance today than they were in the past. Surprisingly, however, even in the presence of sizable markups, recent work by Arkolakis et al. (2019) suggests that for a large class of models, such pro-competitive gains are likely to be quite small overall.

One aspect, however, that has received little attention so far is the extent to which the pro-competitive gains from trade vary across countries and how differences across countries themselves shape these gains. In our view, this is important for at least two main reasons. First, markups and market power are known to vary across countries, for example, due to differences in demand, market concentration, and policy. Therefore, if markups or their responsiveness to trade barriers differ systematically across countries, each economy will likely benefit from changes in competition to a different degree as well. Second, tariffs are rarely imposed uniformly but typically vary significantly across sectors. The extent to which countries protect low-markup versus high-markup sectors will, therefore, matter for the potential pro-competitive gains and provide a way for countries to affect them via policy.

To answer these questions, we develop a multi-country, multi-sector model of international trade with three key forces through which markups vary across markets. First, we allow demand elasticities to be sector- and country-specific, which implies that export and import markups are potentially different within sectors due to differences in demand and the extent of competition. As a consequence, some countries will be net exporters of high-markup goods while others will be net importers. Second, we employ a nested CES demand structure in which demand within and across sectors is potentially differently elastic, resulting in markups that vary with the extent of competition, and we also allow for the possibility that markup variability to competition differs across sectors and countries. Lastly, we allow for detailed differences in firm sizes and market shares, productivity distributions, trade costs, and tariffs across sectors and countries, which results in a rich degree of variation in terms of how competitive import and export markets are for each sector-country pair.

To bring the model to the data, we first estimate about 3,000 distinct sector- and country-specific import demand elasticities within and across sectors for a sample of 29 countries. This approach allows us to determine not only to what extent countries specialize in high- versus low-markup goods but also how this specialization varies across markets. Our estimates have two main implications for the quantitative model. First, we find that richer economies tend to export and import goods with, on average, lower demand elasticities than poor countries do, which we find is driven both by specialization in different industries and variation in country-specific demand across sectors. Second, our estimates suggest that demand is more elastic within than across sectors, which is in line with the existing literature and within our model implies that competition will lower markups.

On the supply side, based on detailed data on the number of firms in each country-sector pair as well as firm-size distributions, we first infer country-sector-specific relative productivity distributions across firms that allow us to solve the model for any given set of sector- and country-pair-specific trade costs as well as country-sector-specific productivities of the best firm. We then employ a Simulated Method of Moments approach to estimate these parameters by matching observed market shares, conditional on differences in demand.

Our estimated parameters, including lower- and upper-tier demand elasticities, productivities, and trade costs, jointly determine equilibrium markups in each sector-country pair and, more importantly, the degree to which markups are variable and respond to changes in market shares. Since markups and their variability to market shares are at the heart of our analysis, we use other data sources to provide supporting evidence for the implied markups and their implications within the structure of our model. In particular, we rely on the ORBIS firm-level data for several countries and show that our model-implied markups are positively correlated with data-driven variable profit margins as well as markups, and are negatively correlated with labor shares. We further show that the extent to which model-implied markups vary with market shares is largely in line with that in the data. Relying on data sources and moments that were not targeted in the estimation, these results lend credence to the parameter estimates and the model structure jointly.

We employ our estimated model to first quantify to what extent the asymmetry between export and import markups shapes the gains from trade. We show that net exporters of high-markup goods benefit from trade disproportionately more than net importers of those products. We show that this result is due to the relocation of profits: Trade essentially allows countries with a comparative advantage in producing high-markup goods to specialize in these products and earn higher profits.[1] Consequently, we document that (i) welfare effects of trade are *positively* related to changes in aggregate markups, and (ii) trade-induced changes in misallocation are *negatively* related to changes in aggregate markups.

To investigate the role of competition and variable markups in the gains from trade, we compute the so-called pro-competitive gains from trade, that is the welfare gains in the presence of variable markups compared to those in a variant of the model with fixed markups (as in, e.g., Arkolakis et al., 2019). This comparison allows us to infer whether or not asymmetric

[1]In line with a large trade literature (see below), profit relocation refers to the incidence of profits from producing some goods or services shifting from producers in one country to those in another country in response to changes in trade costs.

markups affect the "elusiveness" results found in Arkolakis et al. (2019) in a meaningful way. To ensure that our results are indeed driven by variation in demand schedules and not other departures from Arkolakis et al. (2019), we also compare our results to a setting in which demand elasticities are the same across countries, while competition and markups still vary across sectors and countries.

Our analysis delivers four main results. First, we document a high degree of dispersion in the pro-competitive gains from trade across countries, with pro-competitive gains from trade that reach up to 0.8 percentage points in the U.S. and pro-competitive losses of up to 1.5 percentage points in New Zealand, the Netherlands, and the UK. Interestingly, we find that, broadly consistent with Arkolakis et al. (2019), in about two-thirds of countries, the pro-competitive gains are negative, with main exceptions being larger countries such as the U.S. and China for which we predict sizable gains. Therefore, in the majority of cases, increases in markups by exporting partners in response to trade liberalization have more negative welfare effects than markup reductions by domestic firms.

Second, we find that cross-country variation in the pro-competitive gains from trade depends primarily on (1) countries' import shares, and (2) the responsiveness of markups to market shares on imports versus exports. More specifically, we document that countries with a lower import share experience consistently higher pro-competitive gains from trade. Intuitively, while reducing trade costs results in lower markups and markup dispersion for domestic firms, which generates *positive* pro-competitive gains from trade, it also raises the market share and markups of foreign exporters to a country, which creates *negative* pro-competitive gains (Helpman and Krugman, 1989). Since the elasticity of markups with respect to market share is increasing in market shares (Burstein, Carvalho and Grassi, 2020), larger import shares magnify the latter effect and, therefore, dampen the pro-competitive gains from trade, rendering the pro-competitive gains from trade negative. Consequently, our results show that only larger and less open economies experience pro-competitive *gains* from trade.

Third, we find that also the responsiveness of markups to market shares (i.e., the difference between sector- and product-level demand elasticities) on imports and exports noticeably shapes cross-country heterogeneity in the pro-competitive gains from trade. Specifically, on the import side, we find that countries with *larger* inverse elasticities at the upper tier compared to those at the lower tier experience smaller pro-competitive gains from trade. Intuitively, after trade liberalization, foreign firms selling to these countries will increase their markups to a larger extent because of a larger gap between lower- and upper-tier elasticities, which reduces the pro-competitive gains from trade. Consequentially, these countries are more likely to experience *negative* pro-competitive gains from trade. We show that this channel is particularly important when import shares are larger.

On the export side, countries that face *smaller* gaps between inverse elasticities at the upper and lower tier in their export markets experience smaller pro-competitive gains from trade. Since exporters gain market shares after trade liberalization, they increase their markups, incurring an additional gain. If upper and lower-tier elasticities in export markets are similar, however, this increase in export markups and welfare will be small. Taking imports and exports together, we show a negative relationship between the pro-competitive gains from trade and the difference between upper and lower-tier inverse elasticities on imports versus that for exports.

Fourth, we find that when elasticities are homogeneous across countries, pro-competitive effects are small, which is consistent with the findings of Arkolakis et al. (2019) who document small, but negative pro-competitive gains from trade. Hence, this result, at least on average, appears to be robust to using a two-tiered CES framework (Atkeson and Burstein, 2008; Edmond, Midrigan and Xu, 2015) in the presence of rich cross-sector heterogeneity in elasticities, market shares, and competition. The introduction of cross-country heterogeneity in demand elasticities, however, results in quantitatively larger pro-competitive gains and losses and noticeably more dispersion across countries. For some countries, such as the Netherlands or New Zealand, we find the pro-competitive gains to be highly negative, while they are positive for the U.S. and China. Hence, once we allow for more asymmetry in demand and, ultimately, markups, pro-competitive effects tend to become quantitatively more meaningful, and the sign of the pro-competitive gains from trade is highly country-specific.

Lastly, we study to what extent policymakers can affect the pro-competitive gains from trade by investigating the relationship between sectoral variation in tariffs and pro-competitive effects. Specifically, we compare the outcomes of two polar counterfactuals in which the U.S. either taxes sectors with low import shares or high ones. We find that the pro-competitive gains are quite negative and equal -0.24 percentage points when the U.S. taxes primarily sectors with a high import share. On the other hand, pro-competitive effects are close to zero when only sectors with a low import share are targeted. These results, therefore, suggest that countries can affect the pro-competitive effects of trade and tariffs in a meaningful way via variation across sectors.

Related Literature Our paper contributes to an extensive literature on variable markups and the pro-competitive gains from trade (see, e.g., Devarajan and Rodrik, 1991; Atkeson and Burstein, 2008; Melitz and Ottaviano, 2008; Chen, Imbs and Scott, 2009; Behrens and Murata, 2012; Edmond, Midrigan and Xu, 2015; Feenstra and Weinstein, 2017; Melitz, 2018; Arkolakis et al., 2019; Dhyne, Kikkawa and Magerman, 2022; Alviarez et al., 2023; Crowley, Han and Prayer, 2024; Graziano, 2024).[2] Our main contribution to this literature is to determine to what extent asymmetries across countries and sectors in terms of demand, markups, competition, and productivity shape pro-competitive effects of trade and how they vary across countries.

[2]There is also a growing literature on the pro-competitive effects of trade in the presence of labor market imperfections (e.g., MacKenzie, 2021; Gutiérrez, 2022; Firooz, 2023).

For this purpose, our first and main methodological contribution is to develop and quantify a multi-country, multi-sector model of international trade and variable markups, which allows for detailed sectoral and country-specific differences in demand, productivity, trade costs, and markups. In contrast to existing work, our approach allows us to deliver predictions on the pro-competitive gains and losses from trade for a wide range of countries and connect them to the underlying fundamentals. Specifically, we document that the import share is a crucial determinant of the size of pro-competitive effects, while the difference between upper-tier and lower-tier elasticities on imports tends to magnify its importance. Our results hence also complement the findings by Arkolakis et al. (2019) and point to when and why the pro-competitive gains can be small or large. We are unaware of other work that has quantified the pro-competitive gains from trade across a wide range of countries and in the presence of rich heterogeneity, and linked variations in the pro-competitive effects to these underlying fundamentals.

Second, our paper relates to the literature on profit shifting (see, e.g., Spencer and Brander, 1983; Brander and Spencer, 1985; Brander, 1986; Krugman, 1987; Bagwell and Staiger, 2012; Ossa, 2014; Lashkaripour and Lugovskyy, 2023; Firooz and Heins, 2023; Ding, Lashkaripour and Lugovskyy, 2022). Our paper differs from these studies as we allow markups to be variable and thus affected by the degree of competition. The model is, hence, particularly well-suited to understand to what extent the variability of markups mitigates or amplifies the importance of profit shifting in response to tariffs. Our paper also differs from Edmond, Midrigan and Xu (2015), Epifani and Gancia (2011), and Holmes, Hsu and Lee (2014), who also examine the pro-competitive gains from trade, but restrict profit shifting either by considering symmetric countries or abstracting from rich cross-sector-country heterogeneity in competition as well as import versus export markups.[3]

Lastly, our paper relates to the finding of Arkolakis et al. (2019) that pro-competitive gains from trade tend to be small, and we show that even in a multi-sector setting with rich heterogeneity in productivity and trade costs, the pro-competitive gains from trade are small in most countries. However, we document that the introduction of country-specific demand elasticities can generate meaningful pro-competitive gains from trade, especially in countries with small import shares and similar upper and lower-tier demand elasticities. Further, broadly consistent with Arkolakis et al. (2019), we find that for about two-thirds of countries in our sample, the pro-competitive gains from trade are in fact negative, and that pro-competitive gains are primarily of importance for larger countries such as the U.S. or China. To the best of our knowledge, this paper is the first to highlight that pro-competitive *gains* appear to be only realistic for larger and less open economies. Further, in contrast to existing work, we also show that sectoral variation in tariffs can have very different implications for the pro-competitive

[3] Holmes, Hsu and Lee (2014) derive a welfare formula that includes the profit-shifting channel, which they call the "terms of trade effect on markups." They do not, however, either examine or quantify the importance of this channel, which is the focus of the current paper.

gains from trade, hence suggesting a way in which they can be affected by policy.

The paper is organized as follows. Section 2 develops a quantitative multi-sector trade model with imperfect product markets and sector- and country-specific markups. Section 3 describes the data and the procedure to estimate import demand elasticities, trade costs, and productivity. Section 4 employs external data sources to provide supporting evidence for the implied markups and their implications within the structure of our model. Section 5 presents the quantitative results and findings of several counterfactual experiments. Section 6 concludes.

2 The Quantitative Model

2.1 Environment

There are N countries in the world indexed by i and n. Country n is endowed with L_n identical workers/consumers who inelastically supply their labor in a perfectly competitive labor market. There are K sectors in each economy indexed by k. Each sector k consists of $J(k)$ sub-sectors indexed by j and l.

2.2 Preferences and Demand Schedules

A homogeneous final consumption good in country n, Q_n, is produced by perfectly competitive producers according to the following Cobb-Douglas production function

$$Q_n = \Pi_{k=1}^{K} {Q_n^k}^{\alpha_n^k}, \qquad \sum_{k=1}^{K} \alpha_n^k = 1 \quad \forall n \in \{1, ..., N\}, \tag{1}$$

where Q_n^k denotes a composite good in sector k and α_n^k its expenditure share in country n. The composite good Q_n^k is a Constant Elasticity of Substitution (CES) aggregate over its sub-sectors

$$Q_n^k = \left(\sum_{j=1}^{J(k)} (q_n^{j(k)})^{\frac{\sigma_n^k - 1}{\sigma_n^k}} \right)^{\frac{\sigma_n^k}{\sigma_n^k - 1}}, \tag{2}$$

where $q_n^{j(k)}$ is a composite good in sub-sector j belonging to sector k in country n. Parameter σ_n^k measures the elasticity of substitution across the sub-sectors of sector k in country n. Note that these elasticities are allowed to differ across sectors and countries. Equation (2) implies the following demand for the composite good $q_n^{j(k)}$

$$q_n^{j(k)} = \left(\frac{P_n^{j(k)}}{\mathcal{P}_n^k} \right)^{-\sigma_n^k} Q_n^k, \tag{3}$$

where $P_n^{j(k)}$ represents the ideal price index for sub-sector $j(k)$ in country n, and $\mathcal{P}_n^k$ denotes the CES price index for sector k in country n

$$\mathcal{P}_n^k = [\sum_{j=1}^{J(k)} (P_n^{j(k)})^{1-\sigma_n^k}]^{\frac{1}{1-\sigma_n^k}}. \tag{4}$$

Moreover, given the preference structure in (1), consumers in country n face the following price index

$$\mathcal{P}_n = \Pi_{k=1}^K \left(\frac{\mathcal{P}_n^k}{\alpha_n^k}\right)^{\alpha_n^k}. \tag{5}$$

To introduce variable markups into the model, we follow Atkeson and Burstein (2008) and Edmond, Midrigan and Xu (2015) and assume that the composite good $q_n^{j(k)}$ is a CES aggregate over a finite number of varieties from across the world

$$q_n^{j(k)} = [\sum_{i=1}^{N} \sum_{f=1}^{F_{in}^{j(k)}} (q_{in,f}^{j(k)})^{\frac{\sigma_n^{j(k)}-1}{\sigma_n^{j(k)}}}]^{\frac{\sigma_n^{j(k)}}{\sigma_n^{j(k)}-1}}, \tag{6}$$

where $q_{in,f}^{j(k)}$ denotes the demand in country n from firm f in source country i in sub-sector $j(k)$, and $F_{in}^{j(k)}$ is the number of firms in sub-sector $j(k)$ from country i selling to n. We abstract from the extensive margin by assuming that the number of firms in each market is fixed. As Edmond, Midrigan and Xu (2015) shows, since firms on the margin are less productive, this assumption has almost no quantitative effects on the welfare results.[4] The parameter $\sigma_n^{j(k)}$ describes the elasticity of substitution across goods, which is allowed to differ across sub-sectors and countries. Using equation (6), we can solve for the demand $q_{in,f}^{j(k)}$ as

$$q_{in,f}^{j(k)} = (\frac{p_{in,f}^{j(k)}}{P_n^{j(k)}})^{-\sigma_n^{j(k)}} q_n^{j(k)}, \tag{7}$$

where $p_{in,f}^{j(k)}$ denotes the price charged in country n by firm f from country i, and the price index $P_n^{j(k)}$ is given by

$$P_n^{j(k)} = \Big[\sum_{i=1}^{N} \sum_{f=1}^{F_{in}^{j(k)}} (p_{in,f}^{j(k)})^{1-\sigma_n^{j(k)}}\Big]^{\frac{1}{1-\sigma_n^{j(k)}}}. \tag{8}$$

[4]In particular, footnote 8 in Edmond, Midrigan and Xu (2015) reads "the quantitative implications of our model are almost identical when there are no fixed costs."

2.3 Production and Trade Frictions

Firm f from country i in sub-sector $j(k)$ produces its unique variety according to the following Constant Returns to Scale (CRS) technology with labor as the sole input, such that

$$q_{i,f}^{j(k)} = A_{i,f}^{j(k)} l_{i,f}, \tag{9}$$

where $A_{i,f}^{j(k)}$ is the firm-specific productivity in sector $j(k)$ in country i. Given that we abstract from the extensive margin, we assume no fixed costs of production or exporting.

To export a good in sub-sector $j(k)$ from country i to n, producers are subject to an ad valorem tariff $t_{in}^{j(k)}$ and an iceberg cost $d_{in}^{j(k)}$, i.e., to deliver a unit of good $j(k)$ from country i to country n, the producer has to ship $d_{in}^{j(k)} > 1$ units of the good. Total trade frictions can hence be summarized as

$$\tau_{in}^{j(k)} = d_{in}^{j(k)}(1 + t_{in}^{j(k)}),$$

with $\tau_{ii}^{j(k)} = 1$.[5] We assume that firms ship goods only directly from i to n and not via a third country.[6]

2.4 Market Structure

We assume that firms in each sub-sector $j(k)$ in country n engage in a Cournot quantity competition. Specifically, firm f in country i chooses its quantity sold in country n by solving the following profit maximization problem

$$\max_{p_{in,f}^{j(k)}, q_{in,f}^{j(k)}} p_{in,f}^{j(k)} q_{in,f}^{j(k)} - q_{in,f}^{j(k)} [w_i \tau_{in}^{j(k)} / A_{i,f}^{j(k)}], \tag{10}$$

subject to the demand equation (7). The marginal cost of firm f in sub-sector $j(k)$ in country i exporting to country n equals $w_i \tau_{in}^{j(k)} / A_{i,f}^{j(k)}$, where w_i denotes the wage in country i.[7] As Appendix A.1 shows, the first-order condition of this profit maximization problem yields that

[5] Our formulation implicitly assumes that tariffs are applied to c.i.f. prices. As documented by Feenstra and Romalis (2014), this is indeed the case for most countries across the world.

[6] This assumption is equivalent to the assumption that the triangle inequality, $\tau_{ih}^{j(k)} \tau_{hn}^{j(k)} \geq \tau_{in}^{j(k)}$, is satisfied for each combination of countries. In practice, this assumption might particularly affect the impact of trade barriers in so-called entrepôts (see, for example, the recent work by Ganapati, Wong and Ziv, 2022) in our sample, such as Egypt or the UK. Trade barriers in these countries would hence likely have an impact not only on these economies directly, but on trade (and profit shifting) between other parties as well. While incorporating these more complex trade networks is beyond the scope of this paper, it would certainly be of interest for future research to understand how the presence of indirect trade affects pro-competitive gains from trade in the presence of profit shifting.

[7] Notice that the firm in principle receives the price $p_{in,f}^{j(k)}/(1 + t_{in}^{j(k)})$ and the marginal cost of production equals $w_i d_{in}^{j(k)} / A_{i,f}^{j(k)}$. To simplify the exposition, we are basically multiplying the firm's objective function by $(1 + t_{in}^{j(k)})$, which does not change the firm's optimal choice.

the price charged by a firm is an endogenous markup over its marginal cost

$$p_{in,f}^{j(k)} = \mu_{in,f}^{j(k)} \left[\frac{w_i \tau_{in}^{j(k)}}{A_{i,f}^{j(k)}} \right]. \tag{11}$$

The firm's optimal markup equals

$$\mu_{in,f}^{j(k)} = \frac{\varepsilon_{in,f}^{j(k)}}{\varepsilon_{in,f}^{j(k)} - 1}, \tag{12}$$

where $\varepsilon_{in,f}^{j(k)}$ is the demand elasticity that firm f from country i faces in sub-sector $j(k)$ in country n

$$\varepsilon_{in,f}^{j(k)} = \left[\frac{1}{\sigma_n^{j(k)}} (1 - s_{in,f}^{j(k)}) + \frac{1}{\sigma_n^k} s_{in,f}^{j(k)} \right]^{-1}, \tag{13}$$

with $s_{in,f}^{j(k)}$ being the firm's sales share in that market

$$s_{in,f}^{j(k)} = \left[\frac{p_{in,f}^{j(k)}}{P_n^{j(k)}} \right]^{1-\sigma_n^{j(k)}}. \tag{14}$$

Each firm faces an endogenously determined demand elasticity, which equals a market-share-weighted harmonic average of within and across-sector elasticities of substitution. Firms with small market shares within a sub-sector $j(k)$ mostly compete with other firms within their sub-sector and, therefore, face a demand elasticity that is closer to $\sigma_n^{j(k)}$. In contrast, firms with relatively high market shares in sub-sector $j(k)$ face an elasticity that is closer to the upper-tier elasticity σ_n^k. When there is a change in trade frictions $\tau_{in}^{j(k)}$, adjustments in the market share of each firm will, therefore, also affect the distribution of markups. This is what we will explore in our counterfactual exercises.

2.5 Total Expenditure and Welfare

Let I_n denote total expenditure in country n. Given the Cobb-Douglas preferences in (1), consumers in country n spend a fraction α_n^k of their total expenditure on sector k. Thus country n's expenditure on sub-sector $j(k)$ is given by

$$X_n^{j(k)} = \alpha_n^k I_n \left(\frac{P_n^{j(k)}}{\mathcal{P}_n^k} \right)^{1-\sigma_n^k}. \tag{15}$$

Total expenditure in country n consists of workers' wage, firms' profits Y_n, tariff revenue R_n, and trade deficits D_n

$$I_n = w_n L_n + Y_n + R_n + D_n. \tag{16}$$

Given the optimal price equation (11), we can write total profits as

$$Y_n = \sum_{k=1}^{K}\sum_{j=1}^{J(k)}\sum_{i=1}^{N}\sum_{f=1}^{F_{ni}^{j(k)}} \frac{1}{\varepsilon_{ni,f}^{j(k)}} \frac{s_{ni,f}^{j(k)} X_i^{j(k)}}{1+t_{ni}^{j(k)}}. \tag{17}$$

Total tariff revenue earned by country n equals

$$R_n = \sum_{k=1}^{K}\sum_{j=1}^{J(k)}\sum_{i=1}^{N}\sum_{f=1}^{F_{in}^{j(k)}} \frac{t_{in}^{j(k)}}{1+t_{in}^{j(k)}} s_{in,f}^{j(k)} X_n^{j(k)}. \tag{18}$$

Trade deficits D_n are defined as total imports minus total exports

$$D_n = \sum_{k=1}^{K}\sum_{j=1}^{J(k)}\sum_{i=1}^{N}\sum_{f=1}^{F_{in}^{j(k)}} \frac{s_{in,f}^{j(k)} X_n^{j(k)}}{1+t_{in}^{j(k)}} - \sum_{k=1}^{K}\sum_{j=1}^{J(k)}\sum_{i=1}^{N}\sum_{f=1}^{F_{ni}^{j(k)}} \frac{s_{ni,f}^{j(k)} X_i^{j(k)}}{1+t_{ni}^{j(k)}}. \tag{19}$$

It can then be shown that the trade deficit equation (19) implies labor market clearing. Specifically, summing over all sub-sectors j and all sectors k in equation (15) and using equations (16)-(19) allows one to write

$$w_n L_n = \sum_{k=1}^{K}\sum_{j=1}^{J(k)}\sum_{i=1}^{N}\sum_{f=1}^{F_{ni}^{j(k)}} \frac{\varepsilon_{ni,f}^{j(k)}-1}{\varepsilon_{ni,f}^{j(k)}} \frac{s_{ni,f}^{j(k)} X_i^{j(k)}}{1+t_{ni}^{j(k)}}, \tag{20}$$

where the right-hand side equals the total revenue of country n's firms across the world net of profits.

Finally, given the utility function (1), welfare of the representative consumer in country n equals real total expenditure

$$Q_n = \frac{I_n}{\mathcal{P}_n}. \tag{21}$$

2.6 Aggregate Productivity, Markup, and Misallocation

To examine the pro-competitive gains from trade, it will prove useful to derive aggregate productivity and aggregate markup. Following Edmond, Midrigan and Xu (2015), we define aggregate productivity in country i denoted by A_i as[8]

$$Q_i = A_i L_i. \tag{22}$$

[8]Note that Edmond, Midrigan and Xu (2015) consider labor net of fixed costs in their definition of aggregate productivity. Given that we assume no fixed costs, we use total labor here.

Appendix A.2 shows that the aggregate productivity can be written as a quantity-weighted harmonic average of firm-level productivities

$$A_i = \left[\sum_{k=1}^{K} \sum_{j=1}^{J(k)} \Big(\sum_{f=1}^{F_{ii}^{j(k)}} \frac{1}{A_{i,f}^{j(k)}} \frac{q_{ii,f}^{j(k)}}{Q_i} + \sum_{n \neq i} d_{in}^{j(k)} \sum_{f=1}^{F_{in}^{j(k)}} \frac{1}{A_{i,f}^{j(k)}} \frac{q_{in,f}^{j(k)}}{Q_i} \Big) \right]^{-1}. \tag{23}$$

To define misallocation, we first solve for the efficient productivity in each country associated with marginal-cost pricing, that is, when all firms across the world set prices equal to the marginal cost of serving each destination market.[9] Denote this efficient productivity in country i by A_i^{eff}. To solve for this efficient productivity, we solve the model by imposing marginal-cost pricing and then use equation (23). We define misallocation in each country as the percentage difference between efficient productivity and aggregate productivity, that is $1 - A_i/A_i^{eff}$.

We define aggregate markup in country i as

$$\mu_i = \frac{\mathcal{P}_i}{w_i/A_i}. \tag{24}$$

Appendix A.2 shows that the aggregate markup can be written as a revenue-weighted harmonic average of firm-level markups across the world

$$\mu_i = \left[\sum_{k=1}^{K} \sum_{j=1}^{J(k)} \Big(\sum_{f=1}^{F_{ii}^{j(k)}} \frac{1}{\mu_{ii,f}^{j(k)}} \frac{q_{ii,f}^{j(k)} p_{ii,f}^{j(k)}}{\mathcal{P}_i Q_i} + \sum_{n \neq i} \frac{d_{in}^{j(k)}}{\tau_{in}^{j(k)}} \sum_{f=1}^{F_{in}^{j(k)}} \frac{1}{\mu_{in,f}^{j(k)}} \frac{p_{in,f}^{j(k)} q_{in,f}^{j(k)}}{\mathcal{P}_i Q_i} \Big) \right]^{-1}. \tag{25}$$

2.7 Equilibrium

Equilibrium Definition. Given productivities $A_{i,f}^{j(k)}$, elasticities of substitution $\sigma_n^{j(k)}$ and σ_n^k, Cobb-Douglas shares α_n^k, labor endowments L_n, trade deficits D_n, iceberg trade costs $d_{in}^{j(k)}$, number of firms $F_{ni}^{j(k)}$, and ad valorem tariffs $t_{in}^{j(k)}$, an equilibrium is characterized by a vector of wages $\{w_n\}_{n=1}^N \in \mathbf{R}_{++}^N$ that satisfy the equilibrium conditions (4), (8), and (11)-(19).

Solving for the Equilibrium. We briefly explain how we solve for the equilibrium, with more details being provided in Appendix B.1. To solve for the equilibrium, we follow these steps:

1. We start with a guess on the vector of wages $\{w_n\}_{n=1}^N$.

2. Using our guess on wages and information on the number of firms in each market, iceberg

[9] We note that this is the efficient productivity from a global, not necessarily individual countries', perspective. Because of profit shifting and terms of trade effects, marginal-cost pricing is not necessarily welfare maximizing from an individual country's perspective.

costs, tariffs, and productivities, we calculate the marginal cost of firm f from country i serving country n in sub-sector $j(k)$.

3. We solve the system of equations (8) and (11)-(14) and compute firms' market shares, prices, markups, and demand elasticities.

4. From the prices computed above, we use equation (4) to calculate sectoral price indices $\mathcal{P}_n^k$.

5. Use equations (15)-(18) to compute aggregate profits, tariff revenues, sectoral expenditures, and total expenditures.

6. Check the trade deficit equation (19) and update our guess for wages until this equation is satisfied.

To evaluate the gains from trade and the consequences of tariff wars, we repeat the above steps for a counterfactual set of tariffs. We then calculate and report percentage changes in profits, expenditures, prices, and welfare.

2.8 Extension: Incorporating Multinationals

So far, we have assumed that all production in each country is done by its own firms, and as a result, all profits generated in each country are owned by individuals in that country. Given the rising role of multinational companies across the world, and as a robustness exercise, this section adds multinational companies to the model to explore how they affect the pro-competitive gains from trade in the presence of profit shifting.

Let $\gamma_n^{j(k)}$ denote the share of multinational enterprises in the country n's production in sub-sector $j(k)$. Moreover, denote by $\lambda_{in}^{j(k)}$ the share of country i in total multinational activities in sub-sector $j(k)$ in country n. We keep the assumption that labor is immobile between countries, and therefore, multinational enterprises employ labor in the host country. Moreover, we assume that the profits from production are shared between countries based on their share in production. Since part of the profits is owned by foreign countries, country n's total profits Y_n can now be written as

$$Y_n = \sum_{k=1}^{K} \sum_{j=1}^{J(k)} \sum_{i=1}^{N} \sum_{f=1}^{F_{ni}^{j(k)}} (1 - \gamma_n^{j(k)}) \frac{s_{ni,f}^{j(k)} X_i^{j(k)}}{\varepsilon_{ni,f}^{j(k)} (1 + t_{ni}^{j(k)})} + \sum_{k=1}^{K} \sum_{j=1}^{J(k)} \sum_{i=1}^{N} \sum_{m \neq n} \sum_{f=1}^{F_{mi}^{j(k)}} \gamma_m^{j(k)} \lambda_{nm}^{j(k)} \frac{s_{mi,f}^{j(k)} X_i^{j(k)}}{\varepsilon_{mi,f}^{j(k)} (1 + t_{mi}^{j(k)})}, \quad (26)$$

where the first term describes country n's profits earned from production in country n and the second term reflects country n's profits earned in other countries from owning shares of multinational companies.[10]

All the equilibrium conditions stated before hold in this model except for total profits Y_n and trade deficits D_n. In the model with multinationals, the labor market clearing condition can be written more compactly than the trade deficit equation, and we, therefore, work with the former in practice. Specifically, the labor market clearing condition, in this case, is identical to that in the model without multinationals, equation (20), since wage bill equals total revenue of firms residing in country n across the world net of profits regardless of who owns these profits.

Appendix B.2 describes in detail how we solve for the equilibrium in this model.

3 Data and Estimation

3.1 Data

We combine several data sources to quantify the model. First, we use information on imports and exports during the year 2015 from UN Comtrade, disaggregated by 6-digit Harmonized System codes (HS6). We include 29 countries in the analysis, which account for the vast majority of global trade and represent a mix of richer and poorer economies.[11] To capture spending on domestic goods, we match the trade data to information on expenditure on domestic goods provided by the GTAP 8 database for each country.[12] We assume that each upper-tier CES aggregate in equation (2) corresponds to a section in the HS nomenclature (HS1 henceforth), outlined in Tables D.1 and D.2, and we infer α_n^k as the share of total expenditure spent on goods

[10]Note that we do not endogenize the decisions made by multinationals regarding where to locate. In particular, we are assuming that the total share of multinationals, $\gamma_n^{j(k)}$, and the share of each country in multinational activities in other countries, $\lambda_{in}^{j(k)}$, remain unchanged in the counterfactual equilibrium. One can hence interpret our counterfactual results in this robustness exercise as the short-run effects before multinationals decide to relocate in response to changes in trade barriers.

[11]We have included the following countries: Australia, Austria, Bangladesh, Belgium, Brazil, China, Denmark, Egypt, France, Germany, Greece, India, Indonesia, Italy, Japan, Mexico, Netherlands, New Zealand, Norway, Peru, Republic of Korea, Romania, Russian Federation, Spain, Sweden, USA, United Kingdom, Vietnam, and a constructed "Rest of the World." Our selection comprises 29 countries, capturing most of the worldwide trade and representing a composition of richer and poorer countries from various regions. Specifically, we considered the 20 largest economies in terms of GDP, excluding Iran, Saudi Arabia, and Taiwan, due to data limitations in certain dimensions. We have also removed Canada from the analysis, due to several instances in which the units in which quantities are reported change over time. However, none of our results depend on this choice. Additionally, we included six of the world's richest countries in terms of GDP per capita (Austria, Belgium, Denmark, New Zealand, Norway, and Sweden) and six less affluent ones (Bangladesh, Egypt, Greece, Peru, Romania, and Vietnam) to ensure a balanced representation of both richer and poorer nations.

[12]The GTAP database mainly uses national input-output tables to construct each country's expenditure on domestic and foreign goods across sectors, and we use the information on "sales of domestic product, at market prices" as well as "imports, at market prices" to infer a country's domestic expenditure share. Since the information on domestic good spending is provided within GTAP's sectoral classification, which is broader than the HS6 classification, we first crosswalk it to the HS6 level and assume that the domestic share in each HS6 category is equal to that of the corresponding GTAP sector. We then aggregate up further to the HS2 level for the analysis.

produced by sector k in country n. We define a sub-sector $j(k)$ as an HS2 category within an HS1 sector k.[13]

To estimate the elasticity of substitution for each sector-country pair, we use trade data for the period between 1995 and 2015 in each country. To account for frequent changes in the HS classification over time, we construct a time-consistent sectoral classification using an updated version of Van Beveren, Bernard and Vandenbussche (2012) and crosswalk the data in each year accordingly.[14] To infer productivity and trade cost parameters, we also use information on the number of firms by sector and country from the UNIDO Industry Stat 4 Database and data on bilateral distance, free trade agreements, as well as whether or not two countries share a common language or border from CEPII.[15]

The final piece of information we require for the quantitative model is the extent of heterogeneity in the firm size distribution across sectors. For this purpose, we follow Chaney (2008) and Feenstra and Romalis (2014), who use industry-specific estimates of the relationship between firm rank and size to empirically inform the model about the extent of firm-level heterogeneity in terms of productivity in each industry. We adopt this approach and construct an empirical firm size distribution $\mathcal{F}_n^{j(k)}$ for each country and HS2 sector by normalizing the size of the largest firm in each industry and inferring the relative sizes of other firms from the rank-size coefficient.[16] Due to data availability, we assume that the relationship between rank and size can vary by sector but is the same across countries. Specifically, we follow Feenstra and Romalis (2014) and assume that the sectoral rank-size coefficients observed in the U.S. also apply to other countries.

To infer the number of firms from a source country selling a product in a destination country $F_{in}^{j(k)}$, we use the information on the number of exporters from the Exporter Dynamics Database by the World Bank and the number of domestic firms from the UNIDO Industry Stat 4 database. Given that the most productive firms are more competitive and thus are more capable of selling in export markets, we assume that their participation in the export markets depends on their productivity rank. For example, in an illustrative world of three countries, suppose that country A has ten firms. One firm from country A sells to country B, and three firms from A sell to C. Then, the most productive firm in country A will sell to A, B, and C.

[13] This choice is mainly driven by the availability of data on the number of firms in each country and sector which is not readily available for all countries on a more disaggregated level.

[14] More specifically, the issue is that HS categories can change over time and, for example, in some cases, (1) split into multiple new HS codes or (2) several HS codes are merged into one. In those cases, to ensure that categories do not cover different goods in one year versus the other, we keep track of these changes and create categories containing all relevant HS codes. For example, category 722210 splits into 722211 and 722219 in the year 1996, and we, therefore, create a synthetic category that contains all three categories and hence all goods that are part of 722210 in 1995 and before and of 722211 and 722219 afterward.

[15] Since the UNIDO data is reported on the ISIC level, we crosswalk it to the HS classification using concordances provided by the UN Statistics Division and WITS.

[16] Since the reported estimates of these coefficients ζ_k in Feenstra and Romalis (2014) are based on the three-digit SITC classification, we crosswalk them to HS2 product categories.

Table 1: Summary Statistics

Trade, Wages, Tariffs, MNEs, and Markups:

	Mean	Std. Deviation	N
Imports (in mn. $)	204.67	2483.84	71,141
Weight (in mn. kg)	599.93	116,063.70	71,141
Expenditure Shares, α_n^k (in %)	3.89	15.53	74,017
Wage Bill (in bn. $)	2244.18	3702.61	29
Tariff (MFN, ad valorem)	8.46	35.99	71,141
Tariff (applied, ad valorem)	5.86	35.34	71,141
Share of Multinationals in Sector-Country, $\gamma_n^{j(k)}$	0.22	0.11	36,720
Share of Investor in Recipient Country, $\lambda_{in}^{j(k)}$	0.03	0.07	870
Profit Margin (ORBIS data)	1.41	0.38	264,434
Markup (ORBIS data)	1.79	1.15	251,780
Labor Share (ORBIS data)	0.49	0.22	264,415

Number of Firms by Country (across all sectors):

Country	Mean	Median
Australia	744.3	288.0
Austria	208.5	78.5
Bangladesh	290.1	127.5
Belgium	250.4	76.5
Brazil	1582.6	635.0
China	3475.0	1880.0
Denmark	109.5	41.5
France	1517.8	553.5
Germany	1620.7	540.5
Greece	484.0	192.0
India	2032.3	1175.0
Indonesia	255.8	121.5
Italy	3091.1	1097.5
Japan	2147.2	707.5
Korea, Rep.	1476.8	45.0
Mexico	479.7	136.5
Netherlands	102.1	31.0
New Zealand	127.5	47.0
Norway	42.5	27.5
Peru	550.7	191.0
Romania	414.4	153.0
Russia	1871.5	773.0
Vietnam	586.2	224.0
Spain	1400.7	442.0
Sweden	403.0	161.0
Egypt	49.1	23.0
United Kingdom	995.9	294.5
United States	2532.7	934.5

Notes: Imports, weights, expenditure shares, and tariffs are reported at the HS2 level. The wage bill varies by country.

Country A's second and third most productive firms will sell to A and C. The remaining fourth to tenth productive firm will cater only to the domestic market A. Thus, firms' presence in foreign markets is tied to their ranking in the productivity distribution.

We also use information on sector-specific tariffs imposed by countries on each other, which we collect from the WITS database. Specifically, we use applied ad valorem tariffs in each HS2 product category for 2015 and match them to the dataset.

Finally, we use several data sources to compute the share of each country in the profits generated in each sector in foreign countries. To infer the total share of multinationals in each sector-country pair, $\gamma_n^{j(k)}$, we use OECD data on *inward activity of multinationals by industrial sector*. For each country and each of the two-digit ISIC (revision 4) sectors, these data report gross operating surplus by multinationals as well as national totals. Therefore, we can identify the total share of multinationals in gross operating profits in each two-digit ISIC sector country, and we assume that all HS2 sectors belonging to a two-digit ISIC sector have the same share.[17] For countries that do not exist in the OECD data, we use UNCTAD and WDI data to construct the total inflow of FDI stock divided by total capital stock to infer the share of multinationals in that country. Since these data are not sector-specific, for these countries we assume that all sectors have the same share of multinationals.

Lastly, to infer the share of each country in total multinational activities in other countries, $\lambda_{in}^{j(k)}$, we use OECD data on *inward activity of multinationals by investing country*. These data report the gross operating surplus in the manufacturing sector by an investor country in a recipient country. Since detailed information for each sector is not available, we assume these shares are the same across all sectors. Moreover, for the countries not included in the OECD dataset, we use UNCTAD data on inward FDI stock for an investor country in a recipient country.

Table 1 provides detailed summary statistics of the final dataset.

3.2 Estimation of the Elasticities of Substitution

Lower-Tier Elasticities. We estimate lower-level (HS2) elasticities of substitution separately for each country via an approach that is in line with Feenstra (1994), Broda and Weinstein (2006), and Soderbery (2015).[18] Specifically, we first utilize that equation (7) can be written in logs and in first differences with respect to time as

$$\Delta \ln(s_{int,f}^{j(k)}) = -(\sigma_n^{j(k)} - 1)\Delta \ln(p_{int,f}^{j(k)}) + \sigma_n^{j(k)} \Delta P_n^{j(k)}, \tag{27}$$

[17] We use data for 2015 or the closest available year.

[18] Elasticity estimates based on the Feenstra method have been frequently used and referred to in other papers, such as Broda, Limão and Weinstein (2008), Hsieh and Klenow (2009), Khandelwal (2010), or Ossa (2014, 2015). However, Section 5.4 assesses the robustness of our results to using an alternative approach based on Fajgelbaum et al. (2020).

where Δ refers to the change in a variable between periods t and $t+1$. To eliminate the price index from this expression, we difference this equation again with respect to a reference variety m and obtain

$$\Delta^m ln(s^{j(k)}_{int,f}) = -(\sigma^{j(k)}_n - 1)\Delta^m ln(p^{j(k)}_{int,f}) + \xi^{j(k)}_{int,f}, \tag{28}$$

which is log-linear in the price of a variety $p^{j(k)}_{int,f}$. As discussed in more detail below, within our framework and the estimation, a variety refers to an HS6-origin pair selling to a destination n. We further introduce the term $\xi^{j(k)}_{int,f}$ to allow for potential measurement error as well as for unobservable shocks to demand. We note that while firms' optimal pricing decision and equilibrium market shares in our model depend on both upper- and lower-tier elasticities, the relationship between *observed prices and market shares* depends on lower-tier elasticities only, as implied by the model equation (7) or its empirical counterpart in equation (28).

We follow Feenstra (1994), Broda and Weinstein (2006), and Soderbery (2015) and adopt the common assumption that supply is upward-sloping and can be written as

$$\Delta^m ln(p^{j(k)}_{int,f}) = \left[\frac{\kappa^{j(k)}_n}{1+\kappa^{j(k)}_n}\right]\Delta^m ln(s^{j(k)}_{int,f}) + \delta^{j(k)}_{int,f}, \tag{29}$$

where $\kappa^{j(k)}_n$ captures the inverse supply elasticity and $\delta^{j(k)}_{int,f}$ denotes unobservable supply shocks. In this setting, the demand elasticity $\sigma^{j(k)}_n$ can, for example, be readily estimated by using an instrumental-variable approach (using, for example, tariffs, as in Fajgelbaum et al., 2020) or assumptions regarding the relationship between demand and supply shocks (their orthogonality, for example). In the baseline specification, we choose to adopt the common identifying assumption that these shocks are orthogonal (see, e.g., Feenstra, 1994); that is, $E[\xi^{j(k)}_{int,f}\delta^{j(k)}_{int,f}] = 0$, in which case one can multiply the two shocks to convert the structural equations of demand and supply into one estimation equation,

$$\left(\Delta^m ln(p^{j(k)}_{int,f})\right)^2 = \lambda_{1,j(k)}\left(\Delta^m ln(s^{j(k)}_{int,f})\right)^2 + \lambda_{2,j(k)}\left(\Delta^m ln(p^{j(k)}_{int,f})\right)\left(\Delta^m ln(s^{j(k)}_{int,f})\right) + u^{j(k)}_{int,f},$$

where $\lambda_{j(k)} = 1/(\sigma^{j(k)}_n - 1)$. We estimate this equation via the hybrid estimator method (LIML) developed in Soderbery (2015), which addresses potential small sample biases as well as grid search inefficiencies present in previous implementations of Feenstra (1994).[19] In practice,

[19] We find that the resulting estimates are similar if we instead assume supply to be horizontal, that is, when $\Delta^m ln(p^{j(k)}_{int,f}) = \delta^{j(k)}_{int,f}$. The correlation between the estimates of $\sigma^{j(k)}_n$ in these two cases exceeds 40%, and also, the counterfactual results change little depending on which specification is used. This similarity is due to the fact that in line with recent findings by Fajgelbaum et al. (2020), our estimates of the inverse export supply elasticity tend to be small in most sectors: For exporters to the U.S., for example, we estimate a median inverse elasticity of 0.043. Further, less than one-third of inverse export supply elasticities are statistically different from zero, which is consistent with supply being horizontal in the majority of sectors and which results in our

since firm-level information for each country is not readily available, we treat each HS6-origin-destination combination that we observe in the data as one variety.[20]

Upper-Tier Elasticities. Once the lower-tier demand and supply-side parameters, $\sigma_n^{j(k)}$ and $\kappa_n^{j(k)}$, are estimated, we can use them along with the resulting residuals to infer elasticities on the sectoral (HS1) level, σ_n^k. To estimate σ_n^k, we follow Fajgelbaum et al. (2020), who use a similar CES preference structure and estimate the upper-level demand elasticity σ_n^k via a regression that, in our notation, translates into

$$\Delta \ln s_{nt}^{j(k)} = \gamma_{nkt} + (1-\sigma_n^k)\Delta \ln p_{nt}^{j(k)} + \epsilon_{nt}^{j(k)}, \tag{30}$$

where $\gamma_{nkt} = -(1-\sigma_n^k)\Delta \ln \mathcal{P}_{nt}^k$, $s_{nt}^{j(k)} = q_{nt}^{j(k)} p_{nt}^{j(k)} / q_{nt}^k p_{nt}^k$ and

$$\begin{aligned} \Delta \ln p_{nt}^{j(k)} =& \frac{1}{1-\sigma_n^{j(k)}} \ln \left(\sum_{i,f \in \mathcal{C}_{nt}^{j(k)}} s_{int,f}^{j(k)} e^{(1-\sigma_n^{j(k)})\Delta \ln p_{int,f}^{j(k)} + \Delta \xi_{int,f}^{j(k)}} \right) \\ & - \frac{1}{1-\sigma_n^{j(k)}} \ln \frac{S_{nj(k),t+1}(\mathcal{C}_{nj(k)t})}{S_{nj(k),t}(\mathcal{C}_{nj(k)t})}, \end{aligned} \tag{31}$$

where $s_{int}^{j(k)}$ denotes the share of continuing variety i in all continuing varieties, $\mathcal{C}_{nj(k)t}$ is the set of continuing varieties in product $j(k)$ between t and t + 1, and $S_{nj(k),t}(\mathcal{C}_{nj(k)t})$ is the share of the varieties in the set C in the total imports of product k at time t.[21] In line with Fajgelbaum et al. (2020), we assume that the upper-tier elasticity is the same across all sectors.

We do not, however, instrument for $\Delta \ln p_{nt}^{j(k)}$ via tariffs as Fajgelbaum et al. (2020) do, but instead use the inferred supply-side residuals from equation (29) as an instrument. The primary reason for this choice is that there is only little variation in tariffs over time for several

estimates of $\sigma_n^{j(k)}$ being similar in the case in which we impose a horizontal export supply curve a priori in the estimation.

[20]The assumption that each *HS6-source-destination* combination is supplied by one producer is arguably a realistic one for many countries in our sample. For example, Hummels et al. (2014) finds that for Denmark, the median number of exporters in each HS6-destination pair is 1 and equals 3 at the 90th percentile. Moreover, using the World Bank's Exporter Dynamics Database, the median number of exporters in *HS2-destination* pairs for the countries that are part of our sample is as follows: Bangladesh (2), Denmark (4), Egypt (3), Mexico (4), Norway (3), Peru (3), and Spain (10) (For the last three years (2012–2014), these data are reported by the World Bank). We also assessed the importance of this assumption for large destination markets in our sample, like the U.S. To this end, while this data is not available for all countries, we estimated import demand elasticities for the U.S. using HS10-level data, by assuming that a given HS10-origin pair imported by the U.S. is supplied by one producer, which is a weaker assumption. We also repeat the estimation using the U.S. imports at the HS8 level. We find that the estimated elasticities using HS8 or HS10 product categories are highly correlated to those using HS6 categories, with correlation coefficients of 0.44 and 0.56, respectively.

[21]Note that since the model presented in Section 2 is static, it does not readily feature a notion of new or disappearing varieties. Therefore, the first line of equation (31) represents the model-implied relationship between prices and shares. However, given the empirical importance of new varieties (see Broda and Weinstein, 2006), we follow Fajgelbaum et al. (2020) and account for their impact via the term in the second line.

countries, especially compared to the large changes that took place during the U.S.-China trade war used in Fajgelbaum et al. (2020). In particular, we construct an instrument that is a simple average of realized $\delta_{int,f}^{j(k)}$ across continuing varieties

$$\Delta Z_{nt}^{j(k)} = \ln\left(\frac{1}{N_{nt}^{j(k),C}} \sum_{i,f \in \mathcal{C}_{nt}^{j(k)}} e^{\delta_{int,f}^{j(k)}}\right), \tag{32}$$

where $N_{nt}^{j(k),C}$ denotes the number of continuing varieties between periods t and $t+1$. Under the assumptions stated above, in particular the orthogonality between demand and supply side residuals, this instrument affects the equilibrium price but is uncorrelated with the error term on the demand side.[22]

Parameter Estimates. Table 2 summarizes our parameter estimates across countries. As summarized in Part I of this table, among the five sectors with the lowest demand elasticities are works of art, precious stones and pearls, as well as the aircraft industry. In contrast, clothing, aluminum, and furniture are sectors with the highest demand elasticities in our sample. These findings are largely in line with prior expectations and anecdotal evidence. The sectors with low elasticities are for example either frequently mentioned in the context of high markups (precious stones, aircraft, cement) or are highly differentiated (art).[23] On the other end, our estimates suggest that, for example, demand for clothing, furniture, and aluminum is, on average, quite elastic, and firms in these sectors hence earn low markups.

Our estimates are largely consistent with those obtained, for example, by Broda and Weinstein (2006), who estimate median values for $\sigma_n^{j(k)}$ for the U.S. that range from 2.2 to 3.7. As evident from Table 2, the median estimate for most countries falls into this range. We estimate $\sigma_n^{j(k)}$ to be particularly low for Italy, Japan, the U.S., and Egypt. On the other end, we estimate comparably large elasticities of substitution for Vietnam, South Korea, and Austria. Table 2 also shows that most elasticities are precisely estimated, with for the majority of countries more than 80% being significantly greater than 1. More importantly, in the majority of cases, we can also reject that elasticities are the same as those estimated for the U.S., which supports our decision to allow for country-specific import demand elasticities. Specifically, we find that

[22] In principle, one could also use the approach employed in Fajgelbaum et al. (2020) to estimate lower-tier elasticities. We do, however, not do so in the baseline specification for two reasons. First, for more than 50% of country pairs, tariffs equal zero in the data. Second, it is frequently the case that a country does not adjust its tariffs over the sample period against any exporter in a particular industry or only against very few. In those cases, $\sigma_n^{j(k)}$ cannot be estimated for this particular country-sector pair and would for example need to be imputed. The current approach avoids such cases. However, we study the robustness of our results to estimating $\sigma_n^{j(k)}$ via Fajgelbaum et al. (2020)'s approach in Section 5.4.

[23] The low elasticity estimate for cement is likely due to the fact that it can only be shipped for very short distances and is, therefore, rarely traded internationally. In such a case, international price changes will, therefore, affect traded quantities only a little.

Table 2: Distribution of parameter estimates for σ

I. Sectors with the lowest and highest elasticities (lower-tier):

Industry	Median $\sigma_n^{j(k)}$
Works of Art, Collectors' Pieces and Antiques (97)	1.69
Raw Hides, Skins, and Leather (41)	1.76
Precious Stones, Pearls (71)	1.83
Stone, Plaster, Cement (68)	1.85
Aircraft, Spacecraft (88)	1.88
⋮	⋮
Furniture, Bedding, etc. (94)	6.19
Aluminium and Articles thereof (76)	7.04
Books, Newspapers, Pictures (49)	7.37
Cloth. Accessories, not knitted (62)	8.31
Cloth. Accessories, knitted (61)	8.74

II. Demand Elasticities across Countries

	Lower-Tier (σ_{HS2})					Upper-Tier (σ_{HS1})
	Median	1st Quartile	3rd Quartile	Share stat. > 1	Share stat. different from U.S. σ	Estimate
Australia	3.20	1.46	7.18	87.05	67.86	1.07
Austria	5.60	1.64	16.36	85.40	59.42	1.01
Bangladesh	5.41	1.97	12.72	84.17	71.43	1.08
Belgium	2.61	1.60	7.04	92.11	66.67	1.09
Brazil	4.28	1.78	7.54	85.92	73.47	1.07
China	3.71	1.95	7.15	83.22	60.00	1.24
Denmark	2.86	1.61	7.72	92.25	55.56	1.39
France	3.18	1.72	6.92	89.87	60.27	1.01
Germany	4.35	1.69	7.39	89.61	70.00	1.02
Greece	2.33	1.62	4.20	83.21	61.22	1.46
India	3.54	1.56	10.56	92.59	71.43	1.07
Indonesia	2.69	1.71	4.23	88.51	66.00	1.07
Italy	1.70	1.26	3.73	85.23	57.97	1.14
Japan	1.94	1.36	4.37	84.03	60.00	1.07
Rep. of Korea	4.57	3.19	8.91	84.89	51.56	1.01
Mexico	3.97	2.26	7.61	88.19	60.87	1.09
Netherlands	3.70	1.51	12.95	87.79	62.50	1.01
New Zealand	3.38	1.67	9.23	85.81	69.23	1.01
Norway	2.87	1.99	4.19	82.98	67.16	1.07
Peru	2.89	1.50	5.90	79.59	65.63	6.54
Romania	3.25	1.67	6.29	88.36	66.67	1.63
Russia	2.74	1.73	5.36	91.49	69.64	1.01
Vietnam	4.51	2.21	14.42	96.69	85.71	1.01
Spain	3.16	2.13	4.77	84.25	62.16	1.24
Sweden	2.66	1.71	5.16	90.76	68.09	4.83
Egypt	2.16	1.32	4.81	90.32	88.00	1.07
United Kingdom	2.36	1.43	6.51	84.93	63.38	1.07
USA	2.16	1.45	5.37	90.60	-	1.04
ROW	3.05	1.24	10.36	77.16	43.08	1.07

Notes: The first part of this table displays the five sectors with the highest and lowest estimates of $\sigma_n^{j(k)}$ across countries. The second part provides summary statistics for the parameter estimates of σ_n^k and $\sigma_n^{j(k)}$. The former is estimated for 1-digit HS product categories and the latter for 2-digit sectors. The median and quartiles are taken over product categories. Standard errors for $\sigma_n^{j(k)}$ are computed via the delta method and we refer to an estimate as statistically greater than one whenever the corresponding t-statistic exceeds 1.96. The reported fractions are similar when assessing if the estimates are significantly different from 0. Analogously, we assess whether or not the estimates for $\sigma_n^{j(k)}$ are statistically different from the U.S. via two-sided t-tests.

across all potential country-pair-sector combinations, about 70% of elasticities are significantly different.

Generally, we find that about one-third of the variation in the inverse $\sigma_n^{j(k)}$ can be explained by product and importer fixed effects, with nearly 60% of this variation being a result of the elasticity of substitution varying across products. This is consistent with the idea in Feenstra (1994) that product categories are differently differentiated and that certain categories are, hence, more or less substitutable in all countries. Variation across countries, on the other hand, suggests that demand for goods tends to be generally more elastic in some countries than in others—for example, because of varying income levels—which might explain why the median $\sigma_n^{j(k)}$ is comparably high in several poor economies, such as of Vietnam, Mexico, and Bangladesh. The parameter estimates, in general, relate to income as expected. A regression of $\sigma_n^{j(k)}$ on GDP per capita (in logs) suggests that the demand elasticity is about 7% lower in the richest economies compared to the poorest ones.[24] Furthermore, a significant fraction of the variation in the elasticity of substitution is a result of country-product-specific factors. This suggests the presence of country-product-specific determinants of $\sigma_n^{j(k)}$, for example, because of country-product-specific standards, or country-product-specific tastes.

Appendix Tables D.3 and D.4 describe in more detail why our estimates differ across countries. Specifically, these tables summarize each country's three most important import and export sectors, along with the corresponding lower-tier inverse elasticities in each industry. This table offers several main takeaways. First, countries tend to import a similar composition of goods, with machinery and vehicles, for example, being the largest import sectors in most countries. We, however, observe a considerable degree of country-specific variation in demand elasticities within industries. That is, demand for goods in a given sector is differently elastic in one country compared to another, for example, because of differences in income or tastes. For instance, the inverse elasticity of *Electrical Machinery and Equipment* is markedly higher in the UK than in Vietnam or Peru. The export mix, on the other hand, tends to be more dispersed across countries, and developing as well as resource-rich countries (e.g., Bangladesh, Norway, Brazil, or Australia) especially tend to export and import noticeably different goods. Belgium and Denmark, for example, export, on average, relatively low-elasticity goods, which is partially a result of the high export share of *Pharmaceutical Products*. The same is true for India, which has a high export share in *Precious Stones and Pearls*. On the other hand, Bangladesh and Vietnam have a large export share in relatively high-elasticity sectors like clothing and footwear.

We also find that import and export elasticities are frequently quite different within the same country-sector pair; that is, the estimated lower-tier elasticities differ for a country's exports

[24]Note that these results are also consistent with the findings of Simonovska (2015), who estimates that doubling a destination's per capita income results in an 18% increase in the average price.

compared to its imports in the same industry. The three most important import and export sectors in Austria and Germany are identical, for example, but we find that the elasticities for exports are smaller than those for imports in every case. The opposite is true in Italy, where sectoral import elasticities are lower than export ones.

Lastly, the rightmost column of Table 2 summarizes how the estimates on the upper tier compare to the lower-tier demand elasticities described above. We find that these estimates are largely sensible. First, they are lower than the estimated values for $\sigma_n^{j(k)}$ in the vast majority of cases, suggesting that goods within sectors are closer substitutes than across. Within the model, this relationship, therefore, implies that markups will be increasing in firm size, which is consistent with what has been widely documented in previous work. Second, the median and mean across our estimates equals 1.07 and 1.41, respectively, which is in line with the across-sector elasticity of substitution used by Edmond, Midrigan and Xu (2015).

3.3 Estimation of Productivity and Trade Costs

We estimate firm-specific productivity levels in each sector-country pair using information on the relationship between firm rank and size, the number of firms in each sector-country pair, and aggregate domestic market shares. Specifically, for a firm f in a given sub-sector $j(k)$, we use equations (11)-(14) to derive the firm's productivity relative to that of the best firm (indexed by $f = 1$) as a product of the ratio of market shares and markups

$$\frac{A_{n,f}^{j(k)}}{A_{n,1}^{j(k)}} = \left(\frac{s_{nn,f}^{j(k)}}{s_{nn,1}^{j(k)}}\right)^{\frac{1}{\sigma_n^{j(k)}-1}} \frac{\mu_{nn,f}^{j(k)}}{\mu_{nn,1}^{j(k)}}, \tag{33}$$

where markups are themselves a function of market shares, as evident from equations (12) and (13).

To calculate the market share of each firm in the domestic market, $s_{nn,f}^{j(k)}$, we exploit the relationship between firm rank and size. In particular, denoting the total domestic market share of all firms in market n in sub-sector $j(k)$ by $s_{nn}^{j(k)}$, we can write

$$s_{nn}^{j(k)} = \sum_{f=1}^{F_{nn}^{j(k)}} s_{nn,f}^{j(k)}. \tag{34}$$

Manipulating this equation delivers

$$s_{nn,1}^{j(k)} = \frac{s_{nn}^{j(k)}}{\sum_{f=1}^{F_{nn}^{j(k)}} \frac{s_{nn,f}^{j(k)}}{s_{nn,1}^{j(k)}}}. \tag{35}$$

Given the observed domestic share in the numerator and the inferred rank-size distribution in the denominator, we can find the domestic market share of the best producer on the left-hand side. We can then compute the domestic market share of any firm f as

$$s_{nn,f}^{j(k)} = \left(\frac{s_{nn,f}^{j(k)}}{s_{nn,1}^{j(k)}}\right) s_{nn,1}^{j(k)}. \tag{36}$$

Having calculated firms' domestic market shares and given the productivity of the best firm $A_{n,1}^{j(k)}$, we can use equation (33) to compute the productivity of all firms. It remains to infer the productivity of the best firm, which we discuss below.

To estimate the iceberg costs $d_{in}^{j(k)}$ and the best-firm productivity $A_{n,1}^{j(k)}$, we target bilateral market shares in the data. To this end, we use data on the bilateral distance between country pairs i and n ($dist_{in}$) as well as on whether or not two countries share a common border ($border_{in}$), a common language ($lang_{in}$), and if there is a free trade agreement between the two countries (fta_{in}). We impose the following log-linear functional form on iceberg costs

$$log(d_{in}^{j(k)}) = \beta_0^{j(k)} + \beta_1^{j(k)} \times dist_{in} + \beta_2^{j(k)} \times border_{in} + \beta_3^{j(k)} \times lang_{in} + \beta_4^{j(k)} \times fta_{in}. \tag{37}$$

For each sub-sector $j(k)$ separately, we jointly estimate the iceberg cost parameters ($\beta_0^{j(k)}, ..., \beta_4^{j(k)}$) along with the productivity of the best firm in all countries ($A_{n,1}^{j(k)}$) to minimize the distance between model-implied market shares and those observed in the data

$$\min_{\beta_0^{j(k)},\beta_1^{j(k)},\beta_2^{j(k)},\beta_3^{j(k)},\beta_4^{j(k)},\{A_{n,1}^{j(k)}\}_{n=1}^{N}} \left[\log(s_{in}^{j(k),model}) - \log(s_{in}^{j(k),data})\right]^2. \tag{38}$$

This minimization problem for each sub-sector $j(k)$ has $N + 4$ parameters (we normalize the best productivity of ROW in all sub-sectors to one). Given that we have 96 HS2 sub-sectors and 29 countries, we therefore estimate $33 \times 96 = 3,168$ parameters in this procedure.

The intuition behind this estimation procedure is that bilateral market shares depend on bilateral trade costs as well as firms' productivities across the world. To elaborate on this minimization procedure, note that the overall market share of country i in country n and sub-sector $j(k)$ equals

$$s_{in}^{j(k),model} = \sum_{f=1}^{F_{in}^{j(k)}} s_{in,f}^{j(k)} \tag{39}$$

Given the best-firm productivity, we calculate the productivity of all firms in each country as outlined above and given by equation (33). Moreover, given the iceberg cost parameters and all productivities, we calculate the marginal cost of each firm in any source country i serving any destination country n and then solve equations (11)-(14) for the model-implied bilateral

Table 3: Estimates: Productivity and Misallocation

	Productivity		Misallocation
	Mean	Median	
Australia	5.93	6.16	0.1883
Austria	4.54	4.42	0.1585
Bangladesh	0.09	0.08	0.0906
Belgium	4.81	4.81	0.1532
Brazil	1.02	0.94	0.0254
China	1.29	1.33	0.0705
Denmark	5.59	5.58	0.1438
France	4.80	4.73	0.0951
Germany	5.69	5.57	0.0329
Greece	1.54	1.58	0.0478
India	0.19	0.19	0.1681
Indonesia	0.40	0.38	0.1400
Italy	4.12	4.10	0.1304
Japan	4.32	4.14	0.1450
Korea, Rep.	3.45	3.39	0.0062
Mexico	1.14	1.04	0.0979
Netherlands	5.63	5.79	0.1928
New Zealand	3.95	3.87	0.1129
Norway	6.69	6.34	0.1248
Peru	0.55	0.53	0.0582
Romania	1.07	0.85	0.0690
Russia	0.86	0.83	0.0698
Vietnam	0.42	0.28	0.0739
Spain	3.03	2.95	0.1225
Sweden	5.25	5.43	0.1166
Egypt	0.30	0.30	0.1969
United Kingdom	5.55	5.45	0.2321
United States	8.85	9.04	0.1170

Notes: The estimated values in columns (2) and (3) refer to the productivity of the best firm in the respective market. Note that the productivity of the ROW is normalized to one and hence not reported separately in this table.

market shares for each firm.

Table 3 summarizes the resulting productivity estimates in each country, which are largely in line with previous findings. In particular, we find that richer economies are, on average, more productive than poorer ones, with the U.S., Norway, Australia, and Germany being, on average, the most productive in our sample. Productivity is lowest in Bangladesh, India, and Egypt. We also find levels of misallocation (as defined in Section 2.6) that are in line with existing work. Edmond, Midrigan and Xu (2015), for example, report misallocation levels between 7% and 9% in Taiwan, which is much in line with the values we obtain for the East Asian economies in our dataset with, for example, 7.1% for China or, 7.4% for Vietnam. Further, Appendix C plots model-implied market shares against those observed in the data for each upper-tier sector.[25] As evident from these figures, the model matches bilateral market shares well, and the R^2 in most cases exceeds 60%.

4 Supporting Evidence Using Cross-Country Firm-Level Data

The whole set of estimated parameters and variables in the previous section, including lower- and upper-tier substitution elasticities, productivities, trade costs, and number of firms, determine the equilibrium markups in each sector-country pair and also the degree to which markups are variable and respond to changes in market shares. Since markups and their variability with respect to market shares are at the heart of our analysis, in this section we use external data sources to provide supporting evidence for the implied markups and their implications within the structure of our model.

In particular, we first show that our model-implied markups are positively correlated with data-driven variable profit margins as well as markups in several countries, and are negatively correlated with labor shares. We further show that the extent to which model-implied markups vary with market shares is largely in line with that in the data. Taken together, these results are reassuring and lend credence to the parameter estimates and the model structure jointly since, in this section, we rely on data sources and data moments that were not used in estimating the model. These results can be, therefore, viewed as an external validation of the estimated model.

To this end, we rely on the ORBIS firm-level dataset in this section, which provides balance sheet information on both larger and smaller companies in several countries along a wide range of dimensions. We restrict our sample (in both data and model) to eight European countries, for which ORBIS has particularly good coverage, to avoid having to rely on the smaller sample sizes for a range of other countries in the dataset.[26] These countries have a particularly rich data coverage on the key variables that we use here, including revenue, wage bill, capital stock, and material costs. Since our trade data is for 2015, we focus on the same year in our analysis. To limit the impact of outliers, we winsorize all variables at 5% and 95%.

[25] Note that we estimate iceberg costs and productivities for each *lower-tier* CES sub-sector $j(k)$. To save space, however, we plot market shares for each *upper-tier* CES sector k by including all respective sub-sectors.

[26] Specifically, we use data for Austria, Belgium, France, Germany, Italy, Norway, Spain, and Sweden.

4.1 Markups, Variable Profit Margins, and Labor Shares

To provide supporting evidence for the overall markup distribution implied by our estimated model, we construct two measures using ORBIS firm-level data: variable profit margins and markups. As for variable profit margins, we first compute firm-level revenue-variable cost margins defined as sales over the sum of wage bills, material costs, and capital costs for each firm.[27] Table 1 reports summary statistics for the resulting firm-level variable profit margins. We then use the average of these variable profit margins across all companies within HS2 codes in each country as the measure of the sector-country-level variable profit margin, to be compared with our model-implied statistics. We map four-digit SIC codes reported in ORBIS to HS2 codes in our trade data, using the concordance developed by Pierce and Schott (2012).[28]

Furthermore, as for markups, we employ the De Loecker and Warzynski (2012) methodology and estimate firm-level markups in ORBIS. Table 1 reports summary statistics for these estimates. We then take the average markup within each HS2-country pair as the sector-country-level markup. We note that all our results using ORBIS data presented in this section are robust to using cross-firm median, rather than the average in our benchmark, of the respective statistics.

We then employ our estimated model and solve for its equilibrium to show that model-implied markups are positively correlated with data-driven variable profit margins and markups discussed above. To this end, we first note that firms in the model potentially sell to multiple destinations and charge different markups across destinations (depending on their equilibrium market shares as well as substitution elasticities). We define firm-level markups within our model framework as a quantity-weighted average of firms' markups across destinations. As Appendix A.3 shows, this constructed markup of firm f located in country i in sector $j(k)$ is equal to

$$\mu_{i,f}^{j(k)} = \frac{p_{i,f}^{j(k)}}{w_i / A_{i,f}^{j(k)}}, \tag{40}$$

where $p_{i,f}^{j(k)}$ is a quantity-weighted average of prices that this firm charges across the world, and $A_{i,f}^{j(k)}$ and w_i are, as defined before, the firm's productivity and country i's wage, respectively. Appendix A.3 also shows that this constructed firm-level markup is exactly equal to the inverse of firm-level labor share, consistent with the predictions and findings in other papers in the literature (e.g., Edmond, Midrigan and Xu, 2015).[29]

[27] To infer capital costs, we use 10-year government bond yields for each country as the net interest rate, and we assume that the depreciation rate is 10% in all sectors and countries. We infer the capital costs by multiplying firm-level capital stock (which is observable in the data) by the sum of net interest rate and depreciation rate. Results are robust to not including capital costs in the denominator.

[28] Both in our trade data and the concordance table, we use import classifications.

[29] This relationship follows from optimal firm behavior and the observation that each firm's first-order condition implies that the markup should equal the labor elasticity of output (which is one in our framework)

To map model-implied markups to data-driven profit margins and markups, we perform what we did in the data: we take the cross-firm average markup within each HS2-country pair in the model. The results are again robust to using a cross-firm median instead. Encouragingly, we find that the variable profit margins and markups in the ORBIS data are positively correlated with our model-implied markups, with the correlation coefficient being 28% and 30%, respectively.[30]

The negative relationship between markups and labor shares in the model discussed above provides us with another way to evaluate the credibility of our estimated model by testing whether or not sectoral labor shares in the data are indeed correlated with our model-predicted markups. To explore this idea empirically, we compute firm-level labor share in our ORBIS data as wage bills divided by value added (i.e., sales minus material costs).[31] Table 1 reports summary statistics for firm-level labor shares. We then take the cross-firm average labor share within HS2-country pairs and compare them with our model-implied average markups at the HS2-country level constructed above. Interestingly, there is a negative association between labor share in the data and average markups in the model, with a correlation coefficient of -31%.

4.2 Markup Variations with Market Shares

The paper's main focus is on the pro-competitive effects of trade, which depends largely on how markups vary in response to changes in market shares after trade liberalization. The extent to which markups are variable and respond to changes in market shares is, therefore, a key statistic that would govern our counterfactual results. This section examines the relationship between markups and market shares in our model and compares it to that in the ORBIS data to lend credence to the key pro-competitive force in our estimated model as an external validation.

To this end, we regress firm-level labor shares on firm-level market shares for all firms f in country i in sector s, separately for each HS2-country pair:

$$\text{LaborShare}_{fis} = a_0 + a_1 \text{MarketShare}_{fis} + \epsilon_{fis}. \tag{41}$$

Since labor shares are inversely related to markups (as discussed above), this regression provides information on how markups are correlated with market shares. The same insight has been widely used in the literature. Edmond, Midrigan and Xu (2015), for instance, run the same regression and employ the estimates of a_1 and a_1/a_0 to infer the markup distribution and the

divided by the labor share in sales. See also the pioneering work by Hall, Blanchard and Hubbard (1986) and De Loecker and Warzynski (2012) for more details.

[30] We also weight each HS2-country pair by the number of firms we observe for that pair in the ORBIS data, since some HS2-country pairs report only a few firms.

[31] Our result is robust to defining the labor share as wage bill divided by sales.

variability of markups to market shares in their framework.

We run these regressions in both our ORBIS data as well as the estimated model. Since we do not observe the share of foreign firms in each sector-country pair, in both data and model, we construct firm-level market shares as the sales share of a firm among all domestic producers in that sector-country pair.

Encouragingly, we find that the estimates of regression (41) in the model are largely in line with those in the data. In particular, across all HS2-country pairs, the correlation coefficients between the estimated a_1 and a_1/a_0 in the model versus data are 0.34 and 0.40, respectively.

Lastly, the median of a_1 estimates in the ORBIS data across all HS2-country pairs is -2.7, whereas it is -1.8 in the model. While the model performs well in capturing the correlation between markups and market shares in an external data set that was not used in the estimation procedure, this correlation is stronger in the data compared to the model; that is, markups co-move with market shares more strongly in the data compared to the model. Intuitively, this is most likely an artifact of having a relatively coarse lower-tier CES aggregation in our model (i.e., HS2), which pushes lower-tier elasticities downward, limiting the variability of markups.[32] Consequently, the pro-competitive effects of trade that we quantify in the next section can be considered mostly conservative.

5 Counterfactual Analysis

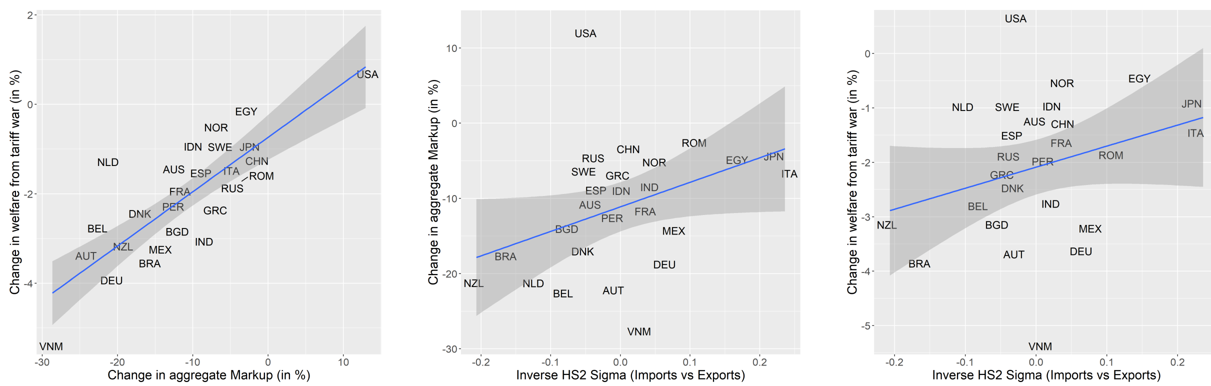
We perform several counterfactual exercises to highlight the joint quantitative importance of variable markups and markup heterogeneity. In our main counterfactual, we simulate the consequences of a global trade war in which all countries raise tariffs by 50 percentage points.[33] We do so in two different ways, one in which firms adjust markups in response to changing competition (i.e, our baseline model), and one in which firms are assumed to be infinitesimal and therefore always face the lower-tier demand elasticity $\sigma_n^{j(k)}$ and charge a constant markup $\sigma_n^{j(k)}/\sigma_n^{j(k)} - 1$. This approach allows us to assess how relevant the pro-competitive gains are in our setting and to understand in which way variable markups affect the model's outcomes.

In addition, we highlight the importance of heterogeneity in demand elasticities by comparing the results of the baseline model to a variant in which $\sigma_n^{j(k)}$ and σ_n^k are assumed to be equal across countries, although our main takeaways regarding the quantitative importance of profit shifting for the pro-competitive gains from trade hold even with homogeneous elasticities across countries. To solve the model and counterfactuals, we follow the approach by Ossa (2014), Caliendo and Parro (2015), Lashkaripour (2020), and Caliendo et al. (2023), among

[32] As noted before, we chose HS2 as our lower-tier aggregation mainly because of data availability on the number of firms in each sector-country pair.

[33] We choose a comparably large change in tariffs to obtain sizable welfare changes in each counterfactual.

Figure 1: Profit Shifting and Welfare Changes across Countries



(a) Welfare and Markups (b) Markups and Elasticities (c) Welfare and Elasticities

Notes: The y-axis in Panels (a) and (c) reports the welfare change associated with a global trade war in which all tariffs are raised by 50 percentage points. The x-axis in Panel (a) and the y-axis in Panel (b) describe the change in the aggregate markup, as derived in Section 2.6. All of these values are reported in percent. The x-axis in Panels (b) and (c) reflects the difference in the trade-weighted average of lower-tier (HS2) inverse elasticities $1/\sigma_n^{j(k)}$ of imports versus that of exports.

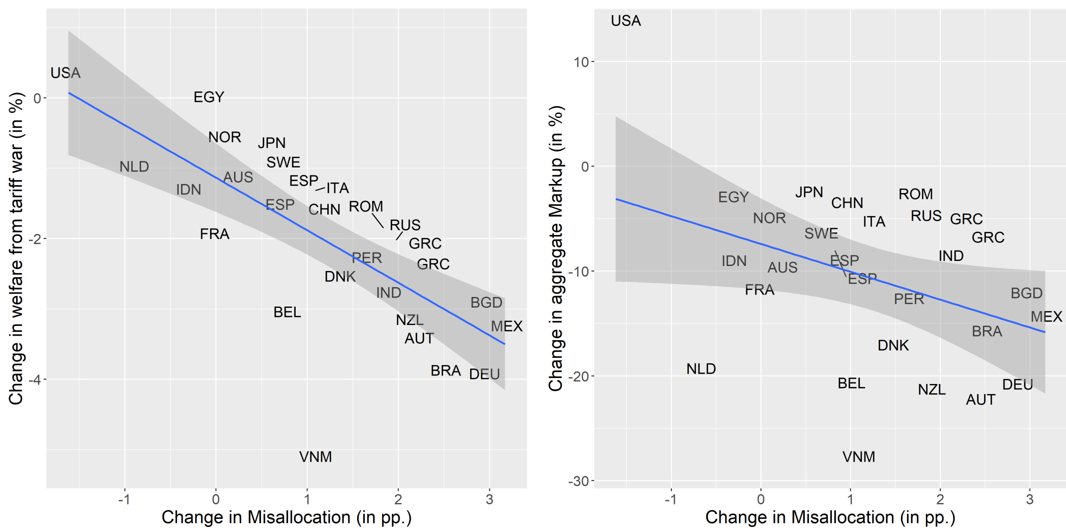
others, and eliminate trade deficits. That is, we first impose trade deficits D_n to be zero and then solve for the equilibrium in both the variable- and fixed-markup models. We assume that trade deficits remain zero in all counterfactual scenarios.

5.1 Profit Shifting, Markups, and Misallocation

We first discuss to what extent welfare changes across countries are driven by changes and the relocation of profits. First, as suggested by Figure 1, the impact of a global tariff war on welfare depends to a large extent on changes in profits and markups. As evident from Panel (a), countries that experience the largest increases in aggregate markups (as derived in equation (25)) tend to also lose the least in terms of welfare from the global tariff war, and vice versa. The correlation coefficient between the change in welfare and the change in the aggregate markup equals 72.8%. Appendix Table D.5 provides a detailed overview of the counterfactual outcomes for each country in our baseline model with variable markups.

As discussed in more detail in Firooz and Heins (2023), the main reason for this relationship is profit shifting. On the one hand, countries that export and specialize in goods with low demand elasticities and, hence, high markups are disproportionately affected by tariffs due to lost profits. On the other hand, firms from countries that have a relatively high share of consumption and imports in high-markup sectors tend to experience large increases in profits, as these firms are now able to capture high profits on goods that were previously imported. Taken together, as shown in Panel (b), the change in the aggregate markup depends positively

Figure 2: Misallocation, Markups, and Welfare



(a) Welfare and Misallocation

(b) Markups and Misallocation

Notes: The y-axis in Panel (a) reports changes in welfare associated with a global trade war in which tariffs are raised by 50 percentage points. The x-axis in both panels reports changes in misallocation. Figure (b) reports the change in aggregate markups on the y-axis.

on the trade-weighted average of lower-tier inverse elasticities $1/\sigma_n^{j(k)}$ for a country's imports relative to its exports with a correlation coefficient of 41.2%. Intuitively, as elaborated below, the average inverse demand elasticities for imports relative to exports is highly indicative of the average profit per dollar that countries pay via imports less the average profit per dollar that countries earn via exports (see equation (17)). Consequentially, as Panel (c) shows, net importers of high markup goods suffer only little from a trade war or might even benefit overall, while net exporters tend to experience larger welfare losses due to disproportionately strong declines in export profits.

It is important to note two observations related to these findings. First, the most relevant elasticities governing profits and profit shifting are lower-tier, not upper-tier, elasticities. This is because exporters are, on average, small relative to total domestic sales, and therefore, markups paid on imports and those earned on exports are mostly driven by lower-tier elasticities (see equation (13)). Consequently, we find that, in practice, upper-tier elasticities do not play a major role for the patterns shown in Figure 1, and we therefore plot predicted welfare changes against variation in lower-tier elasticities in this figure.

Second, the results presented in Figure 1 do not qualitatively depend on the presence of country-specific demand elasticities or on the responsiveness of markups to the degree of competition (i.e., variable markups). In fact, one observes similar relationships in a fixed-markup model with only sectoral variation in demand elasticities (see Figure D.1). In this alternative model, we assume all countries share the same lower- and upper-tier elasticities of substitution as in the U.S. (cross-country homogeneous elasticities, hereafter) and also that firms are infinitesimal and, therefore, face the lower-tier elasticities only. As Figure D.1 show, as long as countries' exports and imports differ in terms of their sectoral composition, the difference between average import and export markups varies across countries, and countries are hence differently affected by profit shifting during a trade war. However, as discussed in more detail below, we find that the incidence of country-sector-specific elasticities tends to magnify the channels that we quantify.

We further investigate changes in misallocation (as defined in Section 2.6) in a global trade war and how they relate to welfare and aggregate markups. As Figure 2a shows, changes in welfare and misallocation are strongly negatively correlated (with a correlation coefficient of -0.76), which is consistent with the findings in the literature (e.g., Edmond, Midrigan and Xu, 2015). That is, countries with a larger increase in misallocation in a global trade war are those experiencing larger welfare losses. As this figure shows, in response to a global trade war, misallocation rises in most countries, with only the U.S. being a notable exception. To explain these cross-country heterogeneous changes in misallocation, Figure 2b plots how changes in misallocation relate to changes in aggregate markups. Interestingly, we show that countries with a larger increase in misallocation are those with a greater decline in aggregate markups. The fact that a decline in aggregate markup is associated with an increase in misallocation is mainly due to the profit-shifting channel. To elaborate, net exporters of high-markup goods experience stronger declines in profits in a global trade war, which translates into greater losses in income. Hence, according to equation (22), aggregate productivity falls, and misallocation rises in those countries.

5.2 The Pro-Competitive Gains from Trade

How important is the variability of markups in this setting, and how large are the pro-competitive gains from trade across countries? We answer these questions via a comparison of the baseline results to those obtained in the fixed-markup variant of the model, as summarized in Table 4.[34] Much of the existing literature discusses the pro-competitive gains from (more) trade, that is, how much larger welfare gains are in the presence of variable markups compared to a fixed-markup variant (see, e.g., Arkolakis et al., 2019). In the present setting, however, we quantify the impact of a tariff war and, hence, of a reduction of trade. Hence, to be consistent with the prior literature, we define the pro-competitive gains from trade as welfare changes under variable markups versus those under fixed markups, but with a reversed sign. Note that since we are considering a *tariff war* counterfactual exercise, more *negative* welfare changes

[34] Appendix Table D.6 presents the counterfactual outcomes for each country within the fixed-markup model in more detail.

Table 4: Global Tariff War (all countries increase tariffs by 50pp)

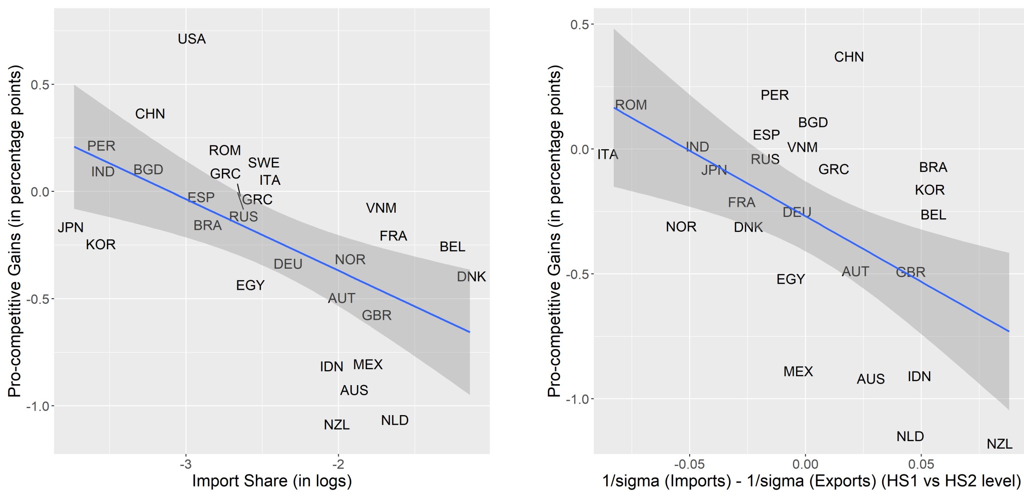
	Variable Markups			Fixed Markups			Pro-Competitive Gains
	Welfare (1)	Wages (2)	Profits (3)	Welfare (4)	Wages (5)	Profits (6)	(4) - (1)
Australia	-1.29	-1.31	-3.13	-2.17	-2.40	-4.33	-0.88
Austria	-3.55	-1.98	-6.82	-4.00	-2.58	-7.63	-0.45
Bangladesh	-3.01	-0.52	-9.88	-2.95	-0.31	-10.18	0.06
Belgium	-2.94	-4.50	-6.26	-3.24	-4.58	-6.95	-0.30
Brazil	-3.72	-2.26	-10.21	-3.83	-2.65	-9.78	-0.11
China	-1.43	-0.78	-3.27	-1.02	-0.92	-2.27	0.41
Denmark	-2.61	-2.44	-5.94	-2.96	-2.71	-6.59	-0.35
France	-1.78	-2.28	-4.30	-2.03	-3.44	-4.18	-0.25
Germany	-3.77	-3.00	-12.75	-4.06	-3.61	-13.00	-0.29
Greece	-2.20	-1.86	-5.34	-2.24	-1.77	-5.52	0.04
India	-2.90	-0.87	-4.43	-2.85	-1.05	-4.40	0.05
Indonesia	-1.11	-4.07	0.18	-1.97	-2.84	-2.82	-0.86
Italy	-1.32	-1.77	-3.26	-1.31	-1.70	-3.29	0.01
Japan	-0.78	-0.61	-1.56	-0.90	-0.62	-1.79	-0.12
S.Korea	-1.19	-0.81	-4.53	-1.39	-1.08	-5.28	-0.20
Mexico	-3.08	-1.14	-9.17	-3.93	-1.62	-11.14	-0.85
Netherlands	-1.12	-3.93	-0.78	-2.23	-3.49	-3.91	-1.11
New Zealand	-3.01	-2.12	-7.91	-4.14	-3.05	-10.01	-1.13
Norway	-0.68	-1.36	-1.51	-0.95	-1.25	-2.40	-0.27
Peru	-2.12	-1.53	-5.55	-1.95	-1.51	-5.21	0.17
Romania	-1.73	-1.18	-5.13	-1.58	-1.09	-5.06	0.15
Russia	-2.03	-0.94	-5.27	-2.03	-1.43	-5.15	0.00
Vietnam	-5.24	-5.05	-11.22	-5.27	-7.03	-9.46	-0.03
Spain	-1.37	-1.77	-2.98	-1.35	-1.98	-2.96	0.02
Sweden	-1.12	-0.99	2.07	-1.03	-0.99	-1.97	0.09
Egypt	-0.32	-1.50	-0.71	-0.80	-1.13	-1.68	-0.48
UK	-1.22	-3.02	-3.00	-1.75	-5.18	-3.14	-0.53
USA	0.51	-1.83	0.69	1.27	-2.03	2.10	0.76
ROW	-0.88	-4.10	-2.08	0.72	-4.56	0.71	1.60

Notes: Columns (1) to (6) report the percentage change in the respective variable, i.e., a value of 1.2 refers to a change in the respective variable by 1.2 percent. All variables are in real terms.

under variable markups compared to fixed markups imply larger pro-competitive *gains from trade*. We consider tariff wars instead of tariff liberalizations since tariffs are generally small in our sample in 2015 and also given the importance and incidence of tariff wars in the past few years. In principle, however, the model can also be readily used to study reductions in iceberg costs instead, and our results are in fact qualitatively similar in that case.

Figure 3 summarizes our findings graphically. We find that variation in the pro-competitive gains across countries depends on three key factors: (1) a country's import share, (2) the difference between lower- and upper-tier elasticities on its imports, and (3) the difference between lower- and upper-tier elasticities on its exports.

Figure 3: Pro-competitive Effects, Demand Elasticities, and Import Shares



(a) Import Shares (b) Demand Elasticities

Notes: The y-axis in Panels (a) and (b) reports the pro-competitive gains (in percentage points), as measured as the difference in the welfare change under fixed versus variable markups associated with a global trade war in which all tariffs are raised by 50 percentage points. The x-axis in Panel (a) reports each country's imports as a fraction of total spending. The x-axis in Panel (b) reflects the difference in the trade-weighted average inverse demand elasticity of imports versus that of exports at the HS1 compared to the HS2 level.

First, as summarized graphically in Panel (a) of Figure 3, we find a high degree of dispersion in the pro-competitive gains from trade across countries, with pro-competitive gains from trade that reach up to 0.8 percentage points in the U.S. and pro-competitive losses of up to 1.5 percentage points in the UK, New Zealand, and the Netherlands. Interestingly, we find that broadly consistent with Arkolakis et al. (2019), in about two-thirds of countries, the pro-competitive gains are negative, with main exceptions being larger countries such as the U.S. and China for which we predict sizable gains.

Second, countries with a lower import share experience higher pro-competitive gains from trade. To understand this result, notice that reducing trade costs activates two opposing pro-competitive effects. On the one hand, it results in lower markups and markup dispersion for domestic firms, which generates *positive* pro-competitive gains from trade. On the other hand, however, it raises the market share and, therefore, markups of foreign exporters to a country, which creates *negative* pro-competitive gains (Helpman and Krugman, 1989). Larger import shares magnify the latter effect and, therefore, dampen the pro-competitive gains from trade, rendering the pro-competitive gains from trade negative. This is because when foreign firms are larger in a market, they adjust their markups to a larger extent in response to changes in trade costs.[35] This property is coming from the fact that in this class of models, the elasticity

[35] Since we impose the same firms' rank-size relationship across countries, larger import shares are associated with larger foreign firms on average.

of markups with respect to market share is increasing in the market share, and larger firms, therefore, adjust their markups to a larger extent (see also Burstein, Carvalho and Grassi, 2020).[36] The model's implication that larger firms adjust their markups by more when facing a trade shock is consistent with the evidence by Tybout (2003) who documents that, in trade liberalization episodes across various countries, larger domestic firms reduce their markups by more compared to smaller ones.

Third, we find that especially the difference between upper- and lower-tier elasticities matters for cross-country variations in the pro-competitive gains from trade. Specifically, on the import side, we find that countries that have *larger* inverse σ_n^k at the upper tier compared to inverse $\sigma_n^{j(k)}$ at the lower tier experience smaller pro-competitive gains from trade (i.e., smaller losses from a trade war under variable than under fixed markups). Intuitively, after a trade war, foreign firms selling to these countries will optimally reduce their markups to a larger extent because of a larger gap between lower- and upper-tier elasticities, which reduces losses from a trade war (i.e., less pro-competitive gains from trade). Consequentially, these countries are more likely to experience *negative* pro-competitive gains from trade.

On the export side, countries that face *smaller* gaps between inverse elasticities at the upper and lower tier in their export markets experience smaller losses from a trade war under variable markups than under fixed markups (i.e., smaller pro-competitive gains from trade). Since exporters are put at a disadvantage through tariffs, their market shares shrink, and they optimally lower their markups, incurring an additional loss. If upper and lower-tier elasticities are similar, however, this decline in export markups and welfare will be small. Taken together, these two mechanisms hence translate into the results presented in Panel (b) of Figure 3, which shows a negative relationship between the pro-competitive gains from trade and the difference between upper and lower tier inverse elasticities on imports versus that for exports.

Lastly, we find that particularly the interplay between import shares and elasticities shapes the pro-competitive gains from trade. To explore this interaction, we regress the pro-competitive gains from trade on import shares, the difference between upper and lower-tier elasticities, and their interaction. Table 5 reports the results. The first two columns in this table confirm that the pro-competitive gains from trade depend negatively on the difference between upper and lower-tier inverse elasticities on the import side as well as the import share. Once we add an interaction term between the two variables, however, the import share loses significance individually, which suggests that the import share is only of importance when the upper- and lower-level elasticities on the import side differ in a meaningful way, and hence import markups adjust more strongly with the competition. To elaborate, in countries with a larger difference between upper- and lower-level elasticities on the import side, higher import shares

[36] Differentiating equation (12) with respect to market share shows that the elasticity of markups with respect to market share is increasing in the market share.

Table 5: Regression Results: The Pro-competitive Gains from Trade

Dependent Variable: Pro-Competitive Gains ($-\Delta\%$ Welfare [$\times 100$] (variable vs fixed markups))				
	(1)	(2)	(3)	(4)
$(1/\sigma)_{HS1} - (1/\sigma)_{HS2}$ (Imports)	-0.9498***	-0.6980***	-2.6509**	-0.6353***
	(0.2382)	(0.2119)	(1.0005)	(0.2102)
log(Import Share)		-0.3510***	0.0619	-0.4007***
		(0.0917)	(0.1480)	(0.0965)
$(1/\sigma)_{HS1} - (1/\sigma)_{HS2}$ (Imports) $\times$ log(Import Share)			-0.6903**	
			(0.3028)	
$(1/\sigma)_{HS1} - (1/\sigma)_{HS2}$ (Exports)				-1.8274
				(1.0927)
R^2	0.22	0.48	0.53	0.52

Notes: The dependent variable in each regression is the percentage change in welfare associated with a 50 percentage point increase in tariffs across all countries under variable compared to fixed markups, but with a negative sign, so that positive values can be interpreted as pro-competitive gains from trade. All values for $1/\sigma$ are weighted by trade volumes. Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

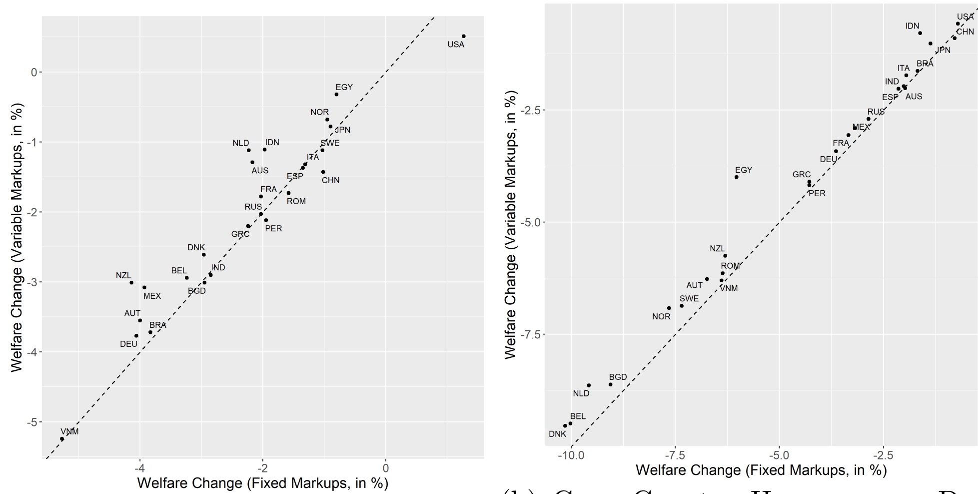
translate into smaller pro-competitive gains from trade: Exporters to these countries will be able to charge higher markups following trade liberalization, especially when exporters have large market shares (i.e., country's large import shares) and therefore adjust their markups significantly (see the discussion above). As column 3 shows, we find that variation in import shares and the difference between upper- and lower-level elasticities on the import side can explain about 53% of the variation in the pro-competitive gains across countries.

The last column in Table 5 adds to the regression the difference between upper and lower-tier elasticities on the export side, but this statistic turns out to be statistically insignificant. The main reason for this result is that countries export to various destinations and there are, therefore, not enough variations in this measure across countries, leading to high standard errors and an insignificant estimate. In practice, therefore, the difference between upper and lower-tier elasticities on the import side plays a more important role in governing the pro-competitive gains from trade compared to that on the export side.

Magnitude of Pro-Competitive Effects. As suggested by Arkolakis et al. (2019), in many standard trade models, the pro-competitive gains from trade will be small due to the effects on domestic and import markups canceling out. In this section, we revisit this conclusion in the presence of profit shifting and cross-country heterogeneity in demand elasticities.

To address especially the importance of the latter in practice, we compare the impact of a

Figure 4: Cross-Country Heterogeneity in Elasticities and the Pro-Competitive Effects of Tariffs



(a) Baseline Model

(b) Cross-Country Homogeneous Demand Elasticities

Notes: Panel (a) plots the change in welfare associated with a global trade war in which tariffs are raised by 50 percentage points in the baseline model with cross-country heterogeneous elasticities. The y-axis reports changes in welfare under variable markups, while the x-axis reports these changes under fixed markups. Panel (b) reports the same outcome in the alternative model with cross-country homogeneous elasticities. All values are reported in percent.

global trade war in the baseline model to an alternative model in which lower and upper-tier elasticities are homogeneous across countries (i.e., using U.S. elasticities). Appendix Tables D.7 and D.8 provides details on counterfactual outcomes in the case of cross-country homogeneous elasticities under variable and fixed markups, respectively.

Figure 4 compares graphically the welfare impact of a global trade war in the baseline model to the model with cross-country homogeneous elasticities. The figure has two main takeaways. First, when elasticities are homogeneous across countries, the model implies relatively small and mostly negative pro-competitive gains from trade, as evident from the fact that most points lie to the left of the 45-degree line. This observation is consistent with the findings of Arkolakis et al. (2019), who document small but negative pro-competitive gains from trade. Hence, this result, at least on average, appears to be robust to using the two-tier CES framework developed in Atkeson and Burstein (2008) and Edmond, Midrigan and Xu (2015), although this framework is not nested by the class of models studied in Arkolakis et al. (2019).

Second, the introduction of cross-country heterogeneity in elasticities results in quantitatively larger pro-competitive gains and losses and noticeably more dispersion across countries, especially compared to the case with homogeneous elasticities, in which most observations lie

Table 6: Counterfactuals: Pro-competitive gains and sectoral variation in tariffs

Policy	Pro-competitive gains in the U.S. (in pp)	Welfare change in the U.S. (%)	
		Fixed Markups	Variable Markups
Taxing sectors with low import share	-0.01	-0.04	-0.03
Taxing sectors with high import share	-0.24	-0.54	-0.30

Notes: The pro-competitive gains (in percentage points) are measured as the difference in the welfare change under fixed versus variable markups. In the first counterfactual only the sectors below the 25th percentile in terms of import share are taxed with an additional 50 percentage points by the United States. In the second counterfactual only the sectors above the 75th percentile in terms of import share are taxed. All other tariffs imposed by the U.S. and other countries are held at factual levels.

close to the 45-degree line.[37] For some countries, such as the Netherlands or New Zealand, we find the pro-competitive gains to be highly negative, while they are moderately positive for the U.S. and China. Hence, once we allow for more asymmetry in demand and, ultimately, markups, pro-competitive effects tend to become quantitatively more meaningful, and the sign of the pro-competitive gains from trade is highly country-specific. Interestingly, due to low import shares, we find larger pro-competitive *gains* mainly for large economies, such as the United States and China. This is consistent with Table 5 that smaller import shares are associated with larger pro-competitive gains. Hence, the positive impact of trade on welfare through product market competition appears to be of particular importance in larger countries, while playing a smaller role in small economies.

5.3 Targeted Policies

To what extent can policymakers affect the pro-competitive gains from trade? To answer this question, we depart from a scenario in which all sectors experience the same tariff increase and focus on the relationship between sectoral variation in tariffs and pro-competitive effects. Specifically, we compare the outcomes of two counterfactuals. In the first one, only sectors below the 25th percentile in terms of import share are taxed with an additional 50 percentage points by the United States. In the second counterfactual, only sectors above the 75th percentile in terms of import share are taxed. All other tariffs imposed by the U.S. and other countries are held at factual levels.

Table 6 summarizes the results and demonstrates that the pro-competitive gains from trade

[37]Notice that the pro-competitive gains from trade measure the *difference* between welfare changes in the variable versus fixed markup models, not the level of welfare changes. As Figure 4 shows, the models with homogeneous elasticities under both fixed and variable markups generate larger changes in welfare compared to those with heterogeneous elasticities. This is because the U.S. elasticities that are used in our models with homogeneous elasticities are generally smaller compared to our models with heterogeneous elasticities, leading to smaller trade elasticities. In fact, changes in import shares in Tables D.7 and D.8 (i.e., with homogeneous elasticities) are smaller than those in Tables D.5 and D.6 (i.e., with heterogeneous elasticities).

are very different in these two cases. We find that the pro-competitive gains are quite negative and equal -0.24 percentage points when the U.S. taxes primarily sectors with a high import share. On the other hand, pro-competitive effects are close to zero when only sectors with a low import share are targeted. These results are in line with the results found above. A tariff increases not only markups imposed by domestic firms but also lowers those imposed by foreign firms, with the latter channel dominating quantitatively when import shares are high. When the U.S. taxes mainly sectors with low import shares, however, both channels are quantitatively similar. These results hence suggest that countries can affect the pro-competitive effects of trade and tariffs via variation across sectors in a meaningful way.

5.4 Robustness and Alternative Models

How important are sectoral heterogeneity, profit shifting, and the presence of multinationals for the results? To answer this question, we perform several counterfactual exercises in which we shut down selected channels of the model or use alternative estimates and compare the results to those obtained in the baseline case.

Heterogeneity in demand elasticities and larger lower-tier elasticities. First, we evaluate the pro-competitive effects of trade in a setting without heterogeneity in elasticities across sectors and countries. To do so, we set all upper-tier elasticities equal to the value estimated for the U.S. and all lower-tier elasticities equal to the median lower-tier elasticity estimated for the United States. The results are presented in Table D.9 and show that the pro-competitive gains from trade are negative for each country in this case. Further, they are comparably small, with a median of -0.13% and an average of -0.23%.

Moreover, as another robustness check in this setting without cross-country and cross-sectoral heterogeneity in elasticities, we employ a larger lower-tier elasticity of 10.5, in line with the estimate in Edmond, Midrigan and Xu (2015), to ensure that our results are not driven by relatively small lower-tier elasticities. As evident from Table D.10, we find that a larger elasticity on the lower tier tends to magnify the results, and we obtain average pro-competitive gains of -0.59%, with a median of -0.44%. Interestingly, we find that the pro-competitive gains are negative for the majority of countries and close to zero for large countries such as the U.S., China, and India. Hence it appears that, in the absence of cross-sectoral and cross-country variation, even larger countries do not experience sizable pro-competitive gains, as evident from both Tables D.9 and D.10. It is worth emphasizing that without cross-country and cross-sectoral heterogeneity in elasticities, the role of profit shifting is very limited since exported and imported products face the same elasticity in the lower tier as well as in the upper tier. As a result, in such a setting, there is no systematic difference between markups on imported products versus those on exported products, which would limit profit shifting between countries.

Trade elasticities across models. Second, one concern when comparing the baseline model with the fixed-markup variant is that, since these models have presumably different trade elasticities, trade shares might respond very differently to tariffs, which complicates the interpretation of the results. For that reason, in an additional robustness check, we ensure that changes in trade are the same across the two models by adjusting the tariff change in the fixed-markup model such that it matches the changes in trade in the baseline model. In particular, for a given country, we increase tariffs across the world (i.e., global tariff war) in the fixed-markup model such that the change in imports for this country matches that in the baseline model. We do this exercise separately for all countries in our sample. Table D.11 summarizes the results and shows that our main results on the pro-competitive gains from trade are very similar to those obtained in the baseline case. Hence, the results hold even when changes in trade are the same across the two models.

Multinational production. Third, we find that the results change only a little when we employ the model with multinational production, as evident from the results presented in Appendix Table D.12. The correlation between the predicted welfare changes in the baseline model and those in the model with multinationals equals 82%. This correlation is even stronger in terms of the pro-competitive gains: The correlation between the pro-competitive gains from trade in the baseline model and those in the model with multinationals equals 91%.

Alternative ways to estimate elasticities. As a final robustness check, we reestimated the demand elasticities via a method that was recently used by Fajgelbaum et al. (2020) and which identifies $\sigma_n^{j(k)}$ and σ_n^k from changes in tariffs. In line with our analysis, we extend their methodology to allow $\sigma_n^{j(k)}$ to be sector-specific in the estimation. There are, however, two complications that prevent us from applying this approach to estimate both sector and country-specific elasticities, as we did in the baseline case: First, for more than 50% of country pairs, tariffs equal zero in the data. Second, it is frequently the case that a country does not adjust its tariffs over the sample period against any exporter in a particular industry or only against very few. In those cases, $\sigma_n^{j(k)}$ cannot be estimated for this particular country-sector pair due to no or too few identifying observations. For that reason, we restrict $\sigma_n^{j(k)}$ to be sector-specific in this part and compare our findings to the corresponding results in the baseline case. Appendix Figure D.2 summarizes the results. We find that also in this specification the pro-competitive gains from trade are negatively correlated with the import share. Hence, countries such as the U.S. and Brazil experience pro-competitive gains from trade, while these gains are negative in the majority of other economies.

6 Conclusion

This paper develops a multi-sector model of international trade and profit shifting in which both import and export markups are endogenously determined and depend on the competitiveness of each market. Further, the markup distributions for both imports and exports are allowed to vary across countries and sectors. Using a rich set of country- and industry-specific import demand elasticities, productivity distributions, trade costs, and tariffs, we determine which countries are net exporters versus net importers of high markup goods and quantify how each country's specialization pattern affects the gains from trade and the nature of profit shifting in response to trade barriers. Our findings suggest that the pro-competitive gains from trade are highly dependent on a country's import share and the difference between sectoral and product-level demand elasticities. We find that the pro-competitive gains are negative in most countries and that only large or less open economies experience pro-competitive gains as opposed to losses. Lastly, we show that especially markup heterogeneity across countries generates more sizable pro-competitive effects than found in previous work.

Especially the asymmetry in pro-competitive effects has potentially important implications for policy as well as for the ability of countries to reach agreements regarding trade and competition. In particular, while larger, less open countries significantly benefit from foreign competition and have therefore incentives to advocate for more competition from abroad, trade tends to have less positive effects in smaller, more open economies due to the distortionary effect of higher markups charged by foreign firms, which also have relevant distributional consequences. The importance of such considerations for optimal trade policy and global inequality would, in our view, be an important area for future research. Our results also highlight that sectoral variation in tariffs can allow countries to affect the pro-competitive effects of trade in either direction. It would be interesting to understand how sectoral tariff variation seen in past trade conflicts or other trade policies have either amplified or mitigated pro-competitive effects and how to characterize optimal tariffs in such cases.

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Appendices

A Derivations

A.1 Optimal Pricing and Markups

This section derives the optimal price-setting rule in our setting. The profit-maximization problem of a firm f is given by

$$\max_{p_{in,f}^{j(k)},q_{in,f}^{j(k)}} p_{in,f}^{j(k)} q_{in,f}^{j(k)} - q_{in,f}^{j(k)} mc_{in,f}^{j(k)}, \tag{42}$$

where $mc_{in,f}^{j(k)}$ denotes the firm's marginal cost. Using the demand schedules, we can rewrite this optimization problem as

$$\max_{p_{in,f}^{j(k)},q_{in,f}^{j(k)}} (q_n^{j(k)})^{1/\sigma_n^k - 1/\sigma_n^{j(k)}} (Q_n^k)^{1/\sigma_n^k} (q_{in,f}^{j(k)})^{\frac{\sigma_n^{j(k)}-1}{\sigma_n^{j(k)}}} \mathcal{P}_n^k - q_{in,f}^{j(k)} mc_{in,f}^{j(k)}. \tag{43}$$

Taking $\mathcal{P}_n^k$ and Q_n^k as given, the first-order condition can be written as

$$\begin{aligned} &\frac{\sigma_n^{j(k)}-1}{\sigma_n^{j(k)}} (q_n^{j(k)})^{1/\sigma_n^k - 1/\sigma_n^{j(k)}} (Q_n^k)^{1/\sigma_n^k} (q_{in,f}^{j(k)})^{-\frac{1}{\sigma_n^{j(k)}}} \mathcal{P}_n^k \\ &+ (1/\sigma_n^k - 1/\sigma_n^{j(k)}) (q_n^{j(k)})^{1/\sigma_n^k - 1/\sigma_n^{j(k)} - 1} \cdot \frac{\partial q_n^{j(k)}}{\partial q_{in,f}^{j(k)}} (Q_n^k)^{1/\sigma_n^k} (q_{in,f}^{j(k)})^{\frac{\sigma_n^{j(k)}-1}{\sigma_n^{j(k)}}} = mc_{in,f}^{j(k)}. \end{aligned} \tag{44}$$

Using Equation (6), we can write

$$\frac{\partial q_n^{j(k)}}{\partial q_{in,f}^{j(k)}} = \left(\frac{q_n^{j(k)}}{q_{in,f}^{j(k)}} \right)^{1/\sigma_n^{j(k)}}, \tag{45}$$

and simplify the first-order condition to

$$\frac{\sigma_n^{j(k)}-1}{\sigma_n^{j(k)}}(q_n^{j(k)})^{1/\sigma_n^k-1/\sigma_n^{j(k)}}(Q_n^k)^{1/\sigma_n^k}(q_{in,f}^{j(k)})^{-\frac{1}{\sigma_n^{j(k)}}}\mathcal{P}_n^k$$

$$+(1/\sigma_n^k-1/\sigma_n^{j(k)})(q_n^{j(k)})^{1/\sigma_n^k-1/\sigma_n^{j(k)}-1}\cdot\left(\frac{q_n^{j(k)}}{q_{in,f}^{j(k)}}\right)^{1/\sigma_n^{j(k)}}(Q_n^k)^{1/\sigma_n^k}(q_{in,f}^{j(k)})^{\frac{\sigma_n^{j(k)}-1}{\sigma_n^{j(k)}}}=mc_{in,f}^{j(k)}\Leftrightarrow$$

$$(q_n^{j(k)})^{1/\sigma_n^k-1/\sigma_n^{j(k)}}(Q_n^k)^{1/\sigma_n^k}(q_{in,f}^{j(k)})^{-\frac{1}{\sigma_n^{j(k)}}}\mathcal{P}_n^k\left[(q_{in,f}^{j(k)})^{\frac{\sigma_n^{j(k)}-1}{\sigma_n^{j(k)}}}(q_n^{j(k)})^{1/\sigma_n^{j(k)}-1}(\frac{1}{\sigma_n^k}-\frac{1}{\sigma_n^{j(k)}})+\frac{\sigma_n^{j(k)}-1}{\sigma_n^{j(k)}}\right]=mc_{in,f}^{j(k)}$$

$$\Leftrightarrow p_{in,f}^{j(k)}\left[(\frac{q_{in,f}^{j(k)}}{q_n^{j(k)}})^{\frac{\sigma_n^{j(k)}-1}{\sigma_n^{j(k)}}}(\frac{1}{\sigma_n^k}-\frac{1}{\sigma_n^{j(k)}})+\frac{\sigma_n^{j(k)}-1}{\sigma_n^{j(k)}}\right]=mc_{in,f}^{j(k)}. \tag{46}$$

Lastly, equation (7) implies that

$$(\frac{q_{in,f}^{j(k)}}{q_n^{j(k)}})^{\frac{\sigma_n^{j(k)}-1}{\sigma_n^{j(k)}}}=(\frac{p_{in,f}^{j(k)}}{P_n^{j(k)}})^{1-\sigma_n^{j(k)}}=s_{in,f}^{j(k)}, \tag{47}$$

where the last equality follows from the definition

$$s_{in,f}^{j(k)}=\frac{p_{in,f}^{j(k)}q_{in,f}^{j(k)}}{\sum_{f'}p_{in,f'}^{j(k)}q_{in,f'}^{j(k)}}, \tag{48}$$

with $s_{in,f}^{j(k)}$ being the sales share in country n of firm f from country i in sub-sector $j(k)$.

Using Equation (47), we can write

$$q_{in,f}^{j(k)}=(\frac{p_{in,f}^{j(k)}}{P_n^{j(k)}})^{-\sigma_n^{j(k)}}q_n^{j(k)}, \tag{49}$$

and the market share becomes

$$s_{in,f}^{j(k)}=\frac{(p_{in,f}^{j(k)})^{1-\sigma_n^{j(k)}}}{\sum_{f'}(p_{in,f'}^{j(k)})^{1-\sigma_n^{j(k)}}}=\frac{(p_{in,f}^{j(k)})^{1-\sigma_n^{j(k)}}}{[(\sum_{f'}(p_{in,f'}^{j(k)})^{1-\sigma_n^{j(k)}})^{1/(1-\sigma_n^{j(k)})}]^{1-\sigma_n^{j(k)}}}=(\frac{p_{in,f}^{j(k)}}{P_n^{j(k)}})^{1-\sigma_n^{j(k)}}. \tag{50}$$

The first-order condition can hence be written as

$$\frac{p_{in,f}^{j(k)}}{mc_{in,f}^{j(k)}}=\frac{1}{\left[s_{in,f}^{j(k)}(\frac{1}{\sigma_n^k}-\frac{1}{\sigma_n^{j(k)}})+\frac{\sigma_n^{j(k)}-1}{\sigma_n^{j(k)}}\right]}. \tag{51}$$

Defining the weighted average of the substitution elasticities as

$$\varepsilon_{in,f}^{j(k)} = \left[\frac{1}{\sigma_n^{j(k)}(1 - s_{in,f}^{j(k)}) + \frac{1}{\sigma_n^k} s_{in,f}^{j(k)}} \right], \tag{52}$$

we have

$$\frac{p_{in,f}^{j(k)}}{mc_{in,f}^{j(k)}} = \frac{\varepsilon_{in,f}^{j(k)}}{\varepsilon_{in,f}^{j(k)} - 1}. \tag{53}$$

A.2 Aggregate Productivity and Aggregate Markup

This section outlines the derivation of aggregate productivity and aggregate markup in our multi-country, multi-sector setting. The total output produced in a country is a function of its aggregate productivity and aggregate labor:

$$Q_i = A_i L_i \tag{54}$$

Total labor is the sum of all the labor each firm employs in all industries:

$$L_i = \sum_k \sum_j \sum_f l_{i,f}^{j(k)} = \sum_k \sum_j \sum_f \frac{q_{i,f}^{j(k)}}{A_{i,f}^{j(k)}} \tag{55}$$

The total quantity of goods produced by a firm f is the good produced for the home market and the foreign market (multiplied by the iceberg costs)

$$q_{i,f}^{j(k)} = q_{ii,f}^{j(k)} + \sum_{n \neq i} d_{in}^{j(k)} q_{in,f}^{j(k)}$$

This gives us

$$A_i = \left[\sum_{k=1}^{K} \sum_{j=1}^{J(k)} \Big(\sum_{f=1}^{F_{ii}^{j(k)}} \frac{1}{A_{i,f}^{j(k)}} \frac{q_{ii,f}^{j(k)}}{Q_i} + \sum_{n \neq i} d_{in}^{j(k)} \sum_{f=1}^{F_{in}^{j(k)}} \frac{1}{A_{i,f}^{j(k)}} \frac{q_{in,f}^{j(k)}}{Q_i} \Big) \right]^{-1} \tag{56}$$

Aggregate markups is the ratio of aggregate price to its marginal cost

$$\mu_i = \frac{\mathcal{P}_i}{w_i / A_i} \implies \frac{1}{\mu_i} = \frac{1}{A_i} \frac{w_i}{\mathcal{P}_i}$$

Substituting Equation (56), we get:

$$\frac{1}{\mu_i} = \Big(\sum_{k=1}^{K}\sum_{j=1}^{J(k)}\Big(\sum_{f=1}^{F_{ii}^{j(k)}}\frac{1}{A_{i,f}^{j(k)}}\frac{q_{ii,f}^{j(k)}}{Q_i} + \sum_{n\neq i} d_{in}^{j(k)}\sum_{f=1}^{F_{in}^{j(k)}}\frac{1}{A_{i,f}^{j(k)}}\frac{q_{in,f}^{j(k)}}{Q_i}\Big)\Big)\frac{w_i}{\mathcal{P}_i}$$

From the pricing equation (11), we get:

$$\mu_i = \left[\sum_{k=1}^{K}\sum_{j=1}^{J(k)}\Big(\sum_{f=1}^{F_{ii}^{j(k)}}\frac{1}{\mu_{ii,f}^{j(k)}}\frac{q_{ii,f}^{j(k)}p_{ii,f}^{j(k)}}{\mathcal{P}_i Q_i} + \sum_{n\neq i}\frac{d_{in}^{j(k)}}{\tau_{in}^{j(k)}}\sum_{f=1}^{F_{in}^{j(k)}}\frac{1}{\mu_{in,f}^{j(k)}}\frac{p_{in,f}^{j(k)}q_{in,f}^{j(k)}}{\mathcal{P}_i Q_i}\Big)\right]^{-1} \tag{57}$$

A.3 Constructing Firm-Level Markups

We define the overall markup of firm f located in country i in sector $j(k)$ as

$$\mu_{i,f}^{j(k)} \equiv \frac{p_{i,f}^{j(k)}}{w_i/A_{i,f}^{j(k)}}, \tag{58}$$

where we define the quantity-weighted average price $p_{i,f}^{j(k)}$ as

$$p_{i,f}^{j(k)} \equiv \frac{p_{ii,f}^{j(k)}q_{ii,f}^{j(k)} + \sum_{n\neq i}\frac{p_{in,f}^{j(k)}}{1+t_{in}^{j(k)}}q_{in,f}^{j(k)}}{q_{i,f}^{j(k)}}, \tag{59}$$

with $q_{i,f}^{j(k)}$ being the total production of this firm

$$q_{i,f}^{j(k)} = q_{ii,f}^{j(k)} + \sum_{n\neq i} d_{in}^{j(k)} q_{in,f}^{j(k)}. \tag{60}$$

Using the optimal pricing in equation (11) to substitute for $p_{in,f}^{j(k)}$, we show that the firm-level markup $\mu_{i,f}^{j(k)}$ is a quantity-weighted average of markups that this firm charges across the world:

$$\mu_{i,f}^{j(k)} = \frac{\mu_{ii,f}^{j(k)}q_{ii,f}^{j(k)} + \sum_{n\neq i}\mu_{in,f}^{j(k)}d_{in}^{j(k)}q_{in,f}^{j(k)}}{q_{i,f}^{j(k)}}. \tag{61}$$

Lastly, plugging equation (59) in equation (58) and using the fact that $q_{i,f}^{j(k)} = A_{i,f}^{j(k)}L_{i,f}^{j(k)}$, it is straightforward to show that the firm-level markup $\mu_{i,f}^{j(k)}$ is exactly equal to the inverse of the firm's labor share.

B Solving for the Equilibrium

B.1 Solving for the Equilibrium in the Baseline Model

As explained in the body of the article, to solve for the equilibrium, we follow the following steps.

1. We start with a guess on the vector of wages $\{w_n\}_{n=1}^{N}$.

2. Using our guess on wages and information on the number of firms in each market, iceberg costs, tariffs, and productivities, we calculate the marginal cost of firm f from country i serving country n in sub-sector $j(k)$.

3. We solve the system of equations (8) and (11)-(14) and compute firms' market shares, prices, markups, and demand elasticities.

4. From the prices computed above, we use equation (4) to calculate sectoral price indices $\mathcal{P}_n^k$.

5. Use equations (15)-(18) to compute aggregate profits, tariff revenues, sectoral expenditures, and total expenditures.

6. Check the trade deficit equation (19) and update our guess for wages until this equation is satisfied.

Step 5 merits further explanation. To solve for aggregate profits and tariff revenues, we solve for aggregate and sectoral expenditures. From equations (16), (17) and (18), we get:

$$I_n = w_n L_n + \sum_{k=1}^{K} \sum_{j=1}^{J(k)} \sum_{i=1}^{N} \sum_{f=1}^{F_{ni}^{j(k)}} \frac{s_{ni,f}^{j(k)}}{\varepsilon_{ni,f}^{j(k)}(1 + t_{ni}^{j(k)})} X_i^{j(k)} + \sum_{k=1}^{K} \sum_{j=1}^{J(k)} \sum_{i=1}^{N} \sum_{f=1}^{F_{in}^{j(k)}} \frac{t_{in}^{j(k)} s_{in,f}^{j(k)}}{1 + t_{in}^{j(k)}} X_n^{j(k)} + D_n \quad (62)$$

Substituting equation (15), we get:

$$\begin{gathered} I_n = w_n L_n + \sum_{i=1}^{N} \left[\sum_{k=1}^{K} \sum_{j=1}^{J(k)} \sum_{f=1}^{F_{ni}^{j(k)}} \frac{s_{ni,f}^{j(k)}}{\varepsilon_{ni,f}^{j(k)}(1 + t_{ni}^{j(k)})} \alpha_i^k \left(\frac{P_i^{j(k)}}{\mathcal{P}_i^k} \right)^{1-\sigma_i^k} \right] I_i + \\ \sum_{k=1}^{K} \sum_{j=1}^{J(k)} \sum_{i=1}^{N} \sum_{f=1}^{F_{in}^{j(k)}} \frac{t_{in}^{j(k)} s_{in,f}^{j(k)}}{1 + t_{in}^{j(k)}} \alpha_n^k \left(\frac{P_n^{j(k)}}{\mathcal{P}_n^k} \right)^{1-\sigma_n^k} I_n + D_n \end{gathered} \quad (63)$$

This can be written as:

$$\left[1-\sum_{k=1}^{K}\sum_{j=1}^{J(k)}\sum_{i=1}^{N}\sum_{f=1}^{F_{in}^{j(k)}}\frac{t_{in}^{j(k)}s_{in,f}^{j(k)}}{1+t_{in}^{j(k)}}\alpha_n^k\left(\frac{P_n^{j(k)}}{\mathcal{P}_n^k}\right)^{1-\sigma_n^k}-\sum_{k=1}^{K}\sum_{j=1}^{J(k)}\sum_{f=1}^{F_{nn}^{j(k)}}\frac{s_{nn,f}^{j(k)}}{\varepsilon_{nn,f}^{j(k)}(1+t_{nn}^{j(k)})}\alpha_n^k\left(\frac{P_n^{j(k)}}{\mathcal{P}_n^k}\right)^{1-\sigma_n^k}\right]I_n$$
$$-\sum_{i\neq n}^{N}\left[\sum_{k=1}^{K}\sum_{j=1}^{J(k)}\sum_{f=1}^{F_{ni}^{j(k)}}\frac{s_{ni,f}^{j(k)}}{\varepsilon_{ni,f}^{j(k)}(1+t_{ni}^{j(k)})}\alpha_i^k\left(\frac{P_i^{j(k)}}{\mathcal{P}_i^k}\right)^{1-\sigma_i^k}\right]I_i=w_nL_n \tag{64}$$

This is a system of N equations and N unknowns to be solved for aggregate expenditure I_n. Let's re-write this system of equations in the matrix form:

$$\Lambda I=\Psi \tag{65}$$

where

$$I=\begin{pmatrix}I_1\\ \vdots\\ \vdots\\ I_N\end{pmatrix}_{N\times 1},\Psi=\begin{pmatrix}w_1L_1\\ \vdots\\ \vdots\\ w_NL_N\end{pmatrix}_{N\times 1}$$

$$\Lambda=(\mathbb{I}_N-\Omega)$$

Here, $\mathbb{I}_N$ is an identity matrix of size N

$$\mathbb{I}_N=\begin{pmatrix}1&0&\dots&0\\0&1&\dots&0\\ \vdots&\vdots&\ddots&\vdots\\0&0&\dots&1\end{pmatrix}_{N\times N}$$

$$\Omega=\begin{pmatrix}\zeta_1+\Pi_{11}&\Pi_{12}&\dots&\Pi_{1N}\\ \Pi_{21}&\zeta_2+\Pi_{22}&\dots&\Pi_{2N}\\ \vdots&\vdots&\ddots&\vdots\\ \vdots&\vdots&\ddots&\vdots\\ \Pi_{N1}&\Pi_{N2}&\dots&\zeta_N+\Pi_{NN}\end{pmatrix}_{N\times N},$$

where

$$\zeta_n=\sum_{k=1}^{K}\sum_{j=1}^{J(k)}\sum_{i=1}^{N}\sum_{f=1}^{F_{in}^{j(k)}}\frac{t_{in}^{j(k)}s_{in,f}^{j(k)}}{1+t_{in}^{j(k)}}\alpha_n^k\left(\frac{P_n^{j(k)}}{\mathcal{P}_n^k}\right)^{1-\sigma_n^k}$$

$$\Pi_{ni} = \left[\sum_{k=1}^{K} \sum_{j=1}^{J(k)} \sum_{f=1}^{F_{ni}^{j(k)}} \frac{s_{ni,f}^{j(k)}}{\varepsilon_{ni,f}^{j(k)}(1+t_{ni}^{j(k)})} \alpha_i^k \left(\frac{P_i^{j(k)}}{\mathcal{P}_i^k} \right)^{1-\sigma_i^k} \right]$$

We solve the system of equations in (68) to get aggregate income. Then use equation (15) to calculate sectoral expenditures. Then, using equations (17),(18), and (19), we can calculate aggregate profits, tariff revenues, and trade deficits.

B.2 Solving for the Equilibrium in the Model with Multinationals

To solve the model with multinational firms, we follow the steps outlined above but incorporate changes to integrate multinational activity. Firstly, in Step 5, we use equation (26) instead of equation (17). Secondly, since in the model with multinationals, the labor market clearing condition can be written more compactly than the trade deficit equation, we use equation (20) in step 6 instead of equation (19).

To solve for aggregate income in Step 5, we use equations (26), (16) and (18):

$$\begin{aligned} I_n = w_n L_n + \sum_{k=1}^{K} \sum_{j=1}^{J(k)} \sum_{i=1}^{N} \sum_{f=1}^{F_{ni}^{j(k)}} (1-\gamma_n^{j(k)}) \frac{s_{ni,f}^{j(k)} X_i^{j(k)}}{\varepsilon_{ni,f}^{j(k)}(1+t_{ni}^{j(k)})} + \\ \sum_{k=1}^{K} \sum_{j=1}^{J(k)} \sum_{i=1}^{N} \sum_{m \neq n} \sum_{f=1}^{F_{mi}^{j(k)}} \gamma_m^{j(k)} \lambda_{nm}^{j(k)} \frac{s_{mi,f}^{j(k)} X_i^{j(k)}}{\varepsilon_{mi,f}^{j(k)}(1+t_{mi}^{j(k)})} + \sum_{k=1}^{K} \sum_{j=1}^{J(k)} \sum_{i=1}^{N} \sum_{f=1}^{F_{in}^{j(k)}} \frac{t_{in}^{j(k)} s_{in,f}^{j(k)}}{1+t_{in}^{j(k)}} X_n^{j(k)} + D_n \end{aligned} \tag{66}$$

Using equation (15), we get:

$$\begin{aligned} I_n = w_n L_n + \sum_{k=1}^{K} \sum_{j=1}^{J(k)} \sum_{i=1}^{N} \sum_{f=1}^{F_{ni}^{j(k)}} (1-\gamma_n^{j(k)}) \frac{s_{ni,f}^{j(k)}}{\varepsilon_{ni,f}^{j(k)}(1+t_{ni}^{j(k)})} \alpha_i^k \left(\frac{P_i^{j(k)}}{\mathcal{P}_i^k} \right)^{1-\sigma_i^k} I_i + \\ \sum_{k=1}^{K} \sum_{j=1}^{J(k)} \sum_{i=1}^{N} \sum_{m \neq n} \sum_{f=1}^{F_{mi}^{j(k)}} \gamma_m^{j(k)} \lambda_{nm}^{j(k)} \frac{s_{mi,f}^{j(k)}}{\varepsilon_{mi,f}^{j(k)}(1+t_{mi}^{j(k)})} \alpha_i^k \left(\frac{P_i^{j(k)}}{\mathcal{P}_i^k} \right)^{1-\sigma_i^k} I_i + \\ \sum_{k=1}^{K} \sum_{j=1}^{J(k)} \sum_{i=1}^{N} \sum_{f=1}^{F_{in}^{j(k)}} \frac{t_{in}^{j(k)} s_{in,f}^{j(k)}}{1+t_{in}^{j(k)}} \alpha_n^k \left(\frac{P_n^{j(k)}}{\mathcal{P}_n^k} \right)^{1-\sigma_n^k} I_n + D_n \end{aligned} \tag{67}$$

This is a system of N equations in N unknowns, which can be written in the matrix form as:

$$\Lambda I = \Psi \tag{68}$$

where

$$I = \begin{pmatrix} I_1 \\ \vdots \\ \vdots \\ I_N \end{pmatrix}_{N\times 1}, \Psi = \begin{pmatrix} w_1 L_1 \\ \vdots \\ \vdots \\ w_N L_N \end{pmatrix}_{N\times 1}$$

$$\Lambda = (\mathbb{I}_N - \Omega)$$

$$\mathbb{I}_N = \begin{pmatrix} 1 & 0 & \dots & 0 \\ 0 & 1 & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & 1 \end{pmatrix}_{N\times N}$$

$$\Omega = \begin{pmatrix} \zeta_1 + \Pi_{11} & \Pi_{12} & \dots & \Pi_{1N} \\ \Pi_{21} & \zeta_2 + \Pi_{22} & \dots & \Pi_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ \vdots & \vdots & \ddots & \vdots \\ \Pi_{N1} & \Pi_{N2} & \dots & \zeta_N + \Pi_{NN} \end{pmatrix}_{N\times N},$$

Here

$$\underset{N\times N}{\Pi_{in}} = \sum_{k=1}^{K}\sum_{j=1}^{J(k)} \begin{pmatrix} (1-\gamma_1^{j(k)}) & \lambda_{12}^{j(k)}\gamma_2^{j(k)} & \dots & \lambda_{1N}^{j(k)}\gamma_N^{j(k)} \\ \lambda_{21}^{j(k)}\gamma_1^{j(k)} & (1-\gamma_2^{j(k)}) & \dots & \lambda_{2N}^{j(k)}\gamma_N^{j(k)} \\ \vdots & \vdots & \ddots & \vdots \\ \vdots & \vdots & \ddots & \vdots \\ \lambda_{N1}^{j(k)}\gamma_1^{j(k)} & \lambda_{N2}^{j(k)}\gamma_2^{j(k)} & \dots & (1-\gamma_N^{j(k)}) \end{pmatrix}_{N\times N} \cdot \begin{pmatrix} \chi_{11}^{j(k)} & \chi_{12}^{j(k)} & \dots & \chi_{1N}^{j(k)} \\ \chi_{21}^{j(k)} & \chi_{22}^{j(k)} & \dots & \chi_{2N}^{j(k)} \\ \vdots & \vdots & \ddots & \vdots \\ \vdots & \vdots & \ddots & \vdots \\ \chi_{N1}^{j(k)} & \chi_{N2}^{j(k)} & \dots & \chi_{NN}^{j(k)} \end{pmatrix}_{N\times N}$$

where

$$\chi_{ni}^{j(k)} = \sum_{f=1}^{F_{ni}^{j(k)}} \frac{s_{ni,f}^{j(k)}}{\varepsilon_{ni,f}^{j(k)}(1+t_{ni}^{j(k)})}\alpha_i^k \left(\frac{P_i^{j(k)}}{\mathcal{P}_i^k}\right)^{1-\sigma_i^k}$$

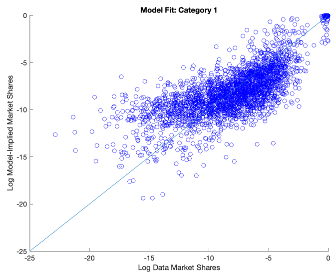
and

$$\zeta_n = \sum_{k=1}^{K}\sum_{j=1}^{J(k)}\sum_{i=1}^{N}\sum_{f=1}^{F_{in}^{j(k)}} \frac{t_{in}^{j(k)} s_{in,f}^{j(k)}}{1+t_{in}^{j(k)}}\alpha_n^k \left(\frac{P_n^{j(k)}}{\mathcal{P}_n^k}\right)^{1-\sigma_n^k}$$

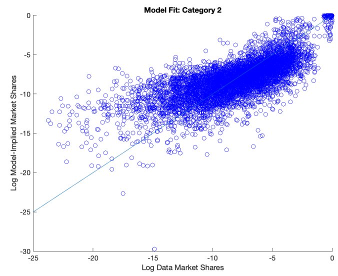
C Market Shares in Data versus Model

The following figures plot the log of market shares in the model against those observed in the data for each upper-tier CES sector.

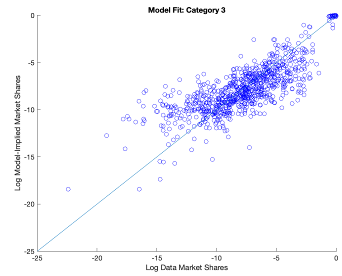
Figure C.1: Log Market Shares (Data) vs Log Market Shares (Model) - Categories 1-12



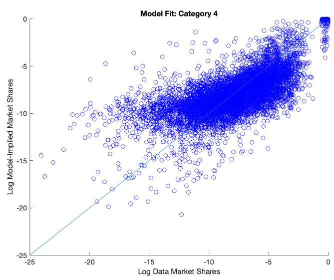
(a) Category 1



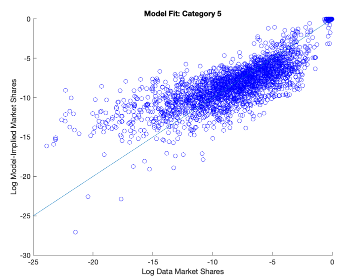
(b) Category 2



(c) Category 3

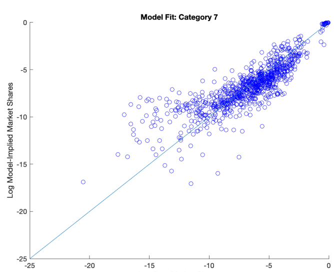


(d) Category 4

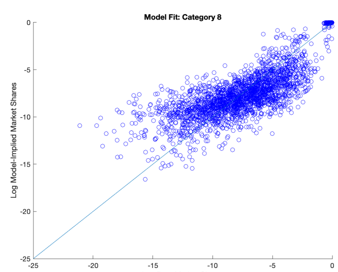


(e) Category 5

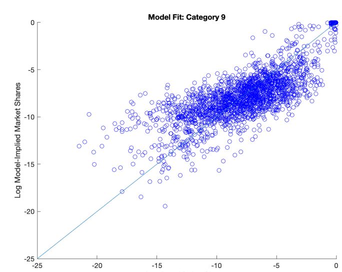
(f) Category 6



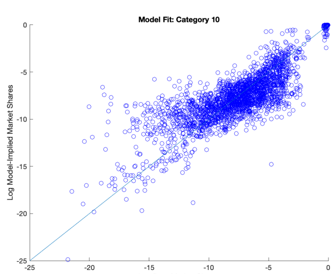
(g) Category 7



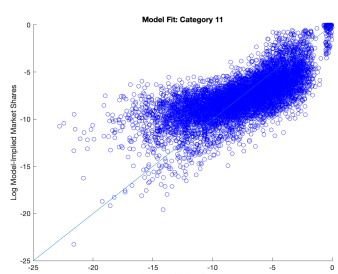
(h) Category 8



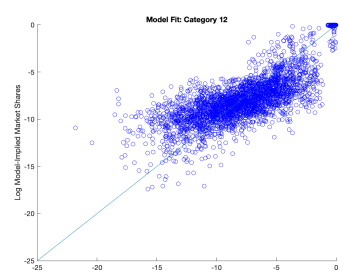
(i) Category 9



(j) Category 10

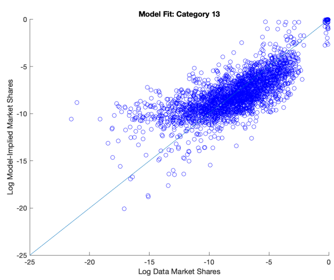


(k) Category 11

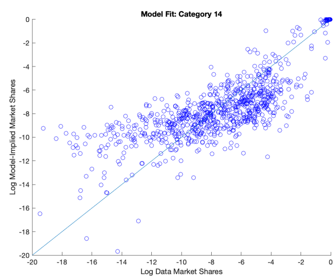


(l) Category 12

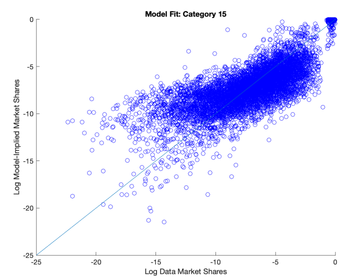
Figure C.2: Log Market Shares (Data) vs Log Market Shares (Model) - Categories 13-21



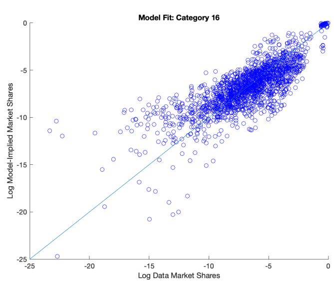
(a) Category 13



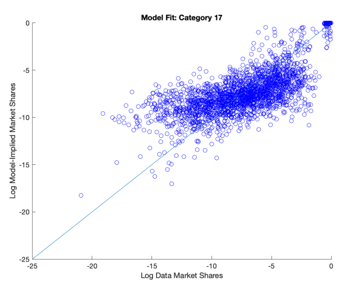
(b) Category 14



(c) Category 15



(d) Category 16



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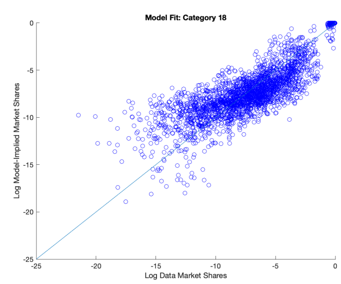
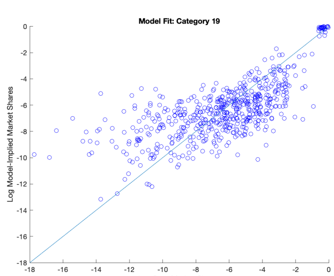
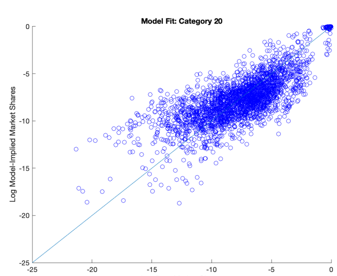


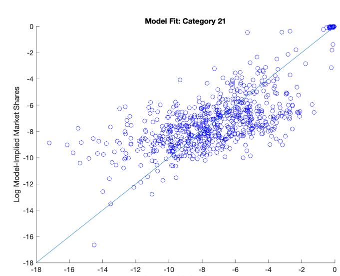
(f) Category 18



(g) Category 19



(h) Category 20



(i) Category 21

D Additional Tables and Figures

Table D.1: HS2 Sector Classification under HS Nomenclature 2012 by World Customs Organization

Section	Name	HS2	Sector Name
01	Live Animals;Animal Products	01	Live animals
		02	Meat & edible meat offal
		03	Fish and crustaceans,molluscs & other aquatic invertebrates
		04	Dairy produce;birds' eggs;natural honey
		05	Products of animal origin
02	Vegetable Products	06	Live trees,bulbs;Roots;flowers
		07	Edible vegetables
		08	Edible fruits; citrus fruits' peels
		09	Coffee,tea, & spices
		10	Cereals
		11	Milling industry products;malts;starch,gluten
		12	Oil seeds & oleaginous fruits; straw and fodder
		13	Lac;gums,raisins & other vegetable extracts
		14	Vegetable plaiting materials
03	Animal or vegetable fats and oils and their Cleavage products; prepared edible fats; Animal or vegetable waxes	15	Animal or vegetable fats;oils
04	Prepared foodstuffs; Beverages, Spirits and Vinegar; Tobacco and Manufactured tobacco Substitutes	16	Preparation of meat, fish or crustaceans, molluscs or aquatic invertebrates
		17	Sugars & sugar confectionery
		18	Cocoa & cocoa preparations
		19	Preparation of cereals,flower, starch,mill, pastrycooks'products
		20	Fruit, nuts or other plant parts
		21	Miscellaneous edible preparations
		22	Beverages,spirits & vinegar
		23	Residues & waste from food industries;prepared animal fodder
		24	Tobacco & manufactured tobacco substitutes
05	Mineral Products	25	Salt;sulphur;earths & stone;lime & cement
		26	Ores,slag & ash
		27	Mineral fuels,mineral oils,distillation products;bituminous substances
06	Products of Chemical or Allied Industries	28	Inorganic chemicals;organic compounds or precious metals
		29	Organic chemicals
		30	Pharmaceutical products
		31	Fertilizers
		32	Tanning & Dyeing extracts; paints & varnishes;ink
		33	Essential oils & resinoids;perfumery,cosmetic or toilet preparations
		34	Soap,washing preparations;waxes,candles;"dental waxes"
		35	Albuminoidal substances; modified starches;glues;enzymes
		36	Explosives;pyrotechnic products;matches;pyrophoric alloys
		37	Photographic or cinematographic goods
		38	Miscellaneous chemical products
07	Plastics and Rubber Articles	39	Plastics & articles thereof
		40	Rubber & articles thereof
08	Raw Hides and Skin, Leather, Fur Skins and Articles thereof; Saddlery and Harness; Travel goods, Handbags and similar containers; Articles of animal gut (other than silk-worm gut)	41	Raw hides & skins(other than fur skins)& leather
		42	Leather articles;saddlery & harness; travel goods,Animal gut
		43	Fur skins & artificial fur; manufactures thereof
09	Wood and articles of Wood; Wood Charcoal; Cork and articles of Cork; Manufactures of straw, of Esparto or of other plaiting materials; Basketware and Wickerwork	44	Wood & wood articles;wood charcoal
		45	Cork & articles of cork
		46	Manufactures of straw,of esparto or other plating materials
10	Pulp of Wood or of other fibrous Cellulosic material; recovered (Waste and scrap) paper or paperboard; paper or paperboard and articles thereof	47	Pulp of Wood or other fibrous cellulosic materials;recovered
		48	Paper & paper board
		49	Printed books,newspapers,pictures;manuscripts,typescripts

Table D.2: HS2 Sector Classification under HS Nomenclature 2012 by World Customs Organization (cont.)

Section	Name	HS2	Sector Name
11	Textiles and Textiles Articles	50	Silk
		51	Wool,fine or coarse animal hair;horse hair,yarn
		52	Cotton
		53	Other vegetable textile fibres;Paper yarn & woven fabrics
		54	Man-made filaments
		55	Man-made staple fibres
		56	Wadding,felt & non-wovens,special yarns
		57	Carpets & other textile floor coverings
		58	Special woven fabrics;tufted woven fabrics;lace;tapestry
		59	Impregnated,coated,covered or laminated textile fabrics
		60	Knitted or croched fabrics
		61	Articles of apparel & clothing accessories,knitted/croched
		62	Articles of apparel & clothing accessories, not knitted or croched
		63	Other made up textile articles;sets;worn clothing;rags
12	Footwear, Headgear, Umbrellas, Sun Umbrellas, Walking-sticks, Seat-Sticks, Whips, Riding-Crops and parts thereof; prepared feathers and articles made therewith ;Artificial flowers; Articles of Human hair	64	Footwear,gaitors
		65	Headgears & parts thereof
		66	Umbrellas,sun umbrellas,walking sticks,seed sticks,whips
		67	Prepared feathers & down;artificial flowers;articles of human hair
13	Articles of stone	68	Articles of stone,plaster,cement,asbestos or mica or similar materials
		69	Ceramic products
		70	Glass & glassware
14	Natural or cultured pearls, precious or semi-precious stones, precious metals, Imitation jewellery;Coin	71	Natural or cultured pearls, precious or semi-precious stones, precious metals
15	Base Metals and Articles of Base Metals	72	Iron & Steel
		73	Articles of Iron or steel
		74	Copper & articles thereof
		75	Nickels & articles thereof
		76	Aluminium & articles thereof
		77	(Reserved for possible future use in the harmonized System)
		78	Lead & articles thereof
		79	Zinc & articles thereof
		80	Tin & articles thereof
		81	Other base metals;cements; articles thereof
		82	Tools,Implements,cutlery,spoons & forks, of base metal;parts thereof of base metal.
		83	Miscellaneous articles of base metal
16	Machinery and mechanical appliances; Electrical equipment; parts thereof; Sound Recorders and Reproducers, Television image and Sound Recorders and Reproducers, and parts and accessories of such articles	84	Nuclear Reactors, Boilers, Machinery mechanical appliances; parts thereof
		85	Electrical machinery & equipment parts; sound recorders & reproducers, television image.
17	Vehicles, Aircraft, Vessels and associated Transport Equipment	86	Railway or tramway locomotives, rolling-stock, railway or tramway track fixtures fittings and parts thereof; mechanical (including electro-mechanical) traffic signalling equipment of all kinds.
		87	Vehicles other than railway or tramway rolling-stock, parts & accessories thereof.
		88	Air crafts,spacecraft, & parts thereof.
		89	Ships, boats & floating structures
18	Optical, Photographic, Cinematographic, Measuring, Checking, Precision, Medical or surgical instruments and Apparatus; Clocks and Watches; Musical Instruments; parts and accessories thereof	90	Optical, photographic, cinematographic, measuring checking, precision, medical or surgical instruments apparatus; parts and accessories thereof.
		91	Clocks & watches;parts thereof
		92	Musical instruments;parts and articles accessories.
19	Arms and Ammunition; parts and accessories thereof	93	Arms and ammunition; parts and accessories thereof.
20	Miscellaneous Manufactured Articles	94	Furniture; bedding, mattresses, mattress supports cushions and similar stuffed furnishings; lamps and lighting fittings, not elsewhere specified or included; illuminated signs, illuminated name-plates and the like; prefabricated buildings.
		95	Toys, games and sports requisites; parts and accessories thereof.
		96	Miscellaneous manufactured articles.
21	Works of Art, Collectors' pieces and Antiques	97	Works of art, collectors' pieces and antiques.

Table D.3: Inverse Lower-Tier Elasticities and Import/Export Shares for each country's largest sectors

	Imports			Exports		
Country	Product Category (HS2 level)	Share	$1/\sigma$	Product Category (HS2 level)	Share	$1/\sigma$
Australia	Elec. Machinery/Equipment (85)	16.94	.31	Ores, Slag, and Ash (26)	27.48	.26
Australia	Vehicles (87)	12.92	.32	Mineral Fuels/Oils, etc. (27)	26.08	.24
Australia	Mineral Fuels/Oils, etc. (27)	11.21	.23	Precious Stones, Pearls (71)	7.24	.32
Austria	Elec. Machinery/Equipment (85)	14.43	.12	Elec. Machinery/Equipment (85)	15.43	.20
Austria	Vehicles (87)	10.82	.18	Machinery, Mech. Appliances (84)	14.11	.19
Austria	Machinery, Mech. Appliances (84)	9.59	.05	Vehicles (87)	9.41	.22
Bangladesh	Cotton (52)	14.89	.05	Cloth. Accessories, not knitted (62)	40.24	.24
Bangladesh	Mineral Fuels/Oils, etc. (27)	10.87	.41	Cloth. Accessories, knitted (61)	38.44	.35
Bangladesh	Machinery, Mech. Appliances (84)	8.18	.05	Paper, Paperboard (48)	4.73	.22
Belgium	Pharmaceutical Products (30)	14.63	.11	Pharmaceutical Products (30)	13.28	.32
Belgium	Mineral Fuels/Oils, etc. (27)	12.18	.24	Mineral Fuels/Oils, etc. (27)	11.61	.24
Belgium	Vehicles (87)	11.61	.05	Vehicles (87)	10.61	.18
Brazil	Elec. Machinery/Equipment (85)	16.04	.09	Ores, Slag, and Ash (26)	12.93	.30
Brazil	Mineral Fuels/Oils, etc. (27)	14.65	.20	Seeds and Grains (12)	11.25	.23
Brazil	Machinery, Mech. Appliances (84)	10.26	.14	Mineral Fuels/Oils, etc. (27)	8.53	.20
China	Elec. Machinery/Equipment (85)	25.91	.08	Elec. Machinery/Equipment (85)	40.06	.20
China	Mineral Fuels/Oils, etc. (27)	12.97	.19	Machinery, Mech. Appliances (84)	6.24	.28
China	Precious Stones, Pearls (71)	6.37	.59	Furniture, Bedding, etc. (94)	3.82	.28
Denmark	Elec. Machinery/Equipment (85)	15.32	.21	Pharmaceutical Products (30)	14.6	.40
Denmark	Vehicles (87)	7.99	.48	Elec. Machinery/Equipment (85)	11.75	.46
Denmark	Machinery, Mech. Appliances (84)	7.53	.19	Machinery, Mech. Appliances (84)	10.37	.25
Egypt	Mineral Fuels/Oils, etc. (27)	13.93	.19	Mineral Fuels/Oils, etc. (27)	28.47	.21
Egypt	Elec. Machinery/Equipment (85)	9.04	.96	Elec. Machinery/Equipment (85)	6.61	.92
Egypt	Vehicles (87)	8.66	.74	Vegetables and Roots (7)	4.76	.75
France	Elec. Machinery/Equipment (85)	12.71	.21	Vehicles (87)	10.37	.37
France	Mineral Fuels/Oils, etc. (27)	10.61	.20	Aircraft, Spacecraft (88)	10.17	.55
France	Vehicles (87)	9.7	.42	Machinery, Mech. Appliances (84)	9.55	.48
Germany	Elec. Machinery/Equipment (85)	17.67	.13	Vehicles (87)	19.63	.26
Germany	Vehicles (87)	9.96	.22	Elec. Machinery/Equipment (85)	14.61	.22
Germany	Machinery, Mech. Appliances (84)	8.19	.28	Machinery, Mech. Appliances (84)	12.83	.30
Greece	Mineral Fuels/Oils, etc. (27)	25.94	.43	Mineral Fuels/Oils, etc. (27)	27.34	.43
Greece	Elec. Machinery/Equipment (85)	8.57	.43	Aluminium & Articles thereof (76)	5.93	.55
Greece	Pharmaceutical Products (30)	8.17	.19	Pharmaceutical Products (30)	5.32	.24
India	Mineral Fuels/Oils, etc. (27)	27.55	.28	Precious Stones, Pearls (71)	13.56	.63
India	Precious Stones, Pearls (71)	15.73	.64	Mineral Fuels/Oils, etc. (27)	12.29	.28
India	Elec. Machinery/Equipment (85)	12.65	.12	Pharmaceutical Products (30)	7.11	.78
Indonesia	Mineral Fuels/Oils, etc. (27)	17.62	.27	Mineral Fuels/Oils, etc. (27)	21.12	.27
Indonesia	Elec. Machinery/Equipment (85)	15.06	.15	Animal/Vegetable Oils & Fats (15)	11.94	.38
Indonesia	Machinery, Mech. Appliances (84)	11.38	.24	Elec. Machinery/Equipment (85)	8.02	.20

Table D.4: Inverse Lower-Tier Elasticities and Import/Export Shares for each country's largest sectors (cont.)

	Imports			Exports		
Country	Product Category (HS2 level)	Share	$1/\sigma$	Product Category (HS2 level)	Share	$1/\sigma$
Italy	Mineral Fuels/Oils, etc. (27)	12.36	.36	Machinery, Mech. Appliances (84)	15.28	.48
Italy	Elec. Machinery/Equipment (85)	10.87	.95	Elec. Machinery/Equipment (85)	10.77	.77
Italy	Vehicles (87)	8.98	.46	Vehicles (87)	8.34	.40
Japan	Mineral Fuels/Oils, etc. (27)	20.88	.33	Elec. Machinery/Equipment (85)	25.4	.34
Japan	Elec. Machinery/Equipment (85)	19.87	.40	Vehicles (87)	20.91	.37
Japan	Pharmaceutical Products (30)	5.67	.80	Machinery, Mech. Appliances (84)	12.48	.21
Mexico	Elec. Machinery/Equipment (85)	30.52	.20	Elec. Machinery/Equipment (85)	28.29	.29
Mexico	Machinery, Mech. Appliances (84)	10.6	.06	Vehicles (87)	24.3	.12
Mexico	Vehicles (87)	9.69	.21	Machinery, Mech. Appliances (84)	9.11	.20
Netherlands	Elec. Machinery/Equipment (85)	19.89	.27	Elec. Machinery/Equipment (85)	17.8	.33
Netherlands	Mineral Fuels/Oils, etc. (27)	14.92	.27	Mineral Fuels/Oils, etc. (27)	15.85	.27
Netherlands	Pharmaceutical Products (30)	5.77	.35	Pharmaceutical Products (30)	9.71	.52
New Zealand	Vehicles (87)	13.53	.05	Dairy, Eggs, Honey (4)	19.06	.32
New Zealand	Elec. Machinery/Equipment (85)	13.4	.29	Meat and Edible Meat (2)	13.92	.26
New Zealand	Mineral Fuels/Oils, etc. (27)	10.08	.09	Wood and Articles of Wood (44)	8.21	.31
Norway	Elec. Machinery/Equipment (85)	13.85	.34	Mineral Fuels/Oils, etc. (27)	48.88	.31
Norway	Vehicles (87)	10.8	.37	Fish, Seafood (3)	12.16	.38
Norway	Machinery, Mech. Appliances (84)	9.59	.32	Elec. Machinery/Equipment (85)	5.36	.33
Peru	Elec. Machinery/Equipment (85)	16.38	.12	Ores, Slag, and Ash (26)	29.75	.27
Peru	Mineral Fuels/Oils, etc. (27)	10.28	.26	Precious Stones, Pearls (71)	17.2	.50
Peru	Machinery, Mech. Appliances (84)	10.03	.21	Fruits and Nuts (8)	6.61	.26
ROW	Elec. Machinery/Equipment (85)	22.28	.33	Mineral Fuels/Oils, etc. (27)	22.38	.30
ROW	Machinery, Mech. Appliances (84)	7.97	.33	Elec. Machinery/Equipment (85)	18	.30
ROW	Vehicles (87)	7.49	.33	Precious Stones, Pearls (71)	6.12	.65
S. Korea	Mineral Fuels/Oils, etc. (27)	23.69	.24	Elec. Machinery/Equipment (85)	35.19	.21
S. Korea	Elec. Machinery/Equipment (85)	23.28	.21	Vehicles (87)	11.32	.20
S. Korea	Machinery, Mech. Appliances (84)	5.07	.22	Machinery, Mech. Appliances (84)	6.95	.25
Romania	Elec. Machinery/Equipment (85)	19.09	.30	Elec. Machinery/Equipment (85)	20.48	.31
Romania	Machinery, Mech. Appliances (84)	9.52	.72	Vehicles (87)	14.12	.26
Romania	Vehicles (87)	8.71	.23	Machinery, Mech. Appliances (84)	7.87	.64
Russia	Elec. Machinery/Equipment (85)	18.13	.23	Mineral Fuels/Oils, etc. (27)	59.59	.30
Russia	Machinery, Mech. Appliances (84)	12.45	.37	Iron and Steel (72)	4.95	.22
Russia	Vehicles (87)	8.55	.20	Precious Stones, Pearls (71)	3.2	.67
Spain	Mineral Fuels/Oils, etc. (27)	13.9	.23	Vehicles (87)	18.53	.24
Spain	Vehicles (87)	12.75	.17	Elec. Machinery/Equipment (85)	7.01	.21
Spain	Elec. Machinery/Equipment (85)	10.9	.19	Machinery, Mech. Appliances (84)	6.81	.21
USA	Elec. Machinery/Equipment (85)	21.96	.46	Elec. Machinery/Equipment (85)	15.1	.44
USA	Vehicles (87)	12.78	.05	Machinery, Mech. Appliances (84)	11.14	.42
USA	Mineral Fuels/Oils, etc. (27)	8.91	.56	Vehicles (87)	8.84	.06
UK	Elec. Machinery/Equipment (85)	14.12	.93	Vehicles (87)	12.67	.37
UK	Vehicles (87)	12.73	.42	Machinery, Mech. Appliances (84)	11.14	.23
UK	Machinery, Mech. Appliances (84)	8.09	.20	Precious Stones, Pearls (71)	10.67	.29
Vietnam	Elec. Machinery/Equipment (85)	28.95	.12	Elec. Machinery/Equipment (85)	38.56	.21
Vietnam	Machinery, Mech. Appliances (84)	9.08	.25	Footwear (64)	8.43	.21
Vietnam	Iron and Steel (72)	4.81	.22	Clothing Acc., not knitted (62)	6.35	.23

Table D.5: Global Tariff War (all countries increase tariffs by 50pp), Variable Markups

	Welfare	Wages	Profits			Import Share	Prices
			Overall	Domestic	Export		
Australia	-1.29	-1.31	-3.13	0.01	-61.69	-71.07	-0.17
Austria	-3.55	-1.98	-6.82	-2.18	-63.74	-75.42	8.88
Bangladesh	-3.01	-0.52	-9.88	-1.82	-61.92	-68.82	19.74
Belgium	-2.94	-4.50	-6.26	1.16	-56.76	-66.09	3.45
Brazil	-3.72	-2.26	-10.21	1.04	-64.32	-70.15	6.54
China	-1.43	-0.78	-3.27	-0.37	-64.02	-70.29	6.33
Denmark	-2.61	-2.44	-5.94	0.17	-59.74	-69.08	7.61
France	-1.78	-2.28	-4.30	0.35	-52.26	-64.69	0.58
Germany	-3.77	-3.00	-12.75	3.14	-63.53	-72.84	9.68
Greece	-2.20	-1.86	-5.34	-0.54	-52.22	-53.17	8.84
India	-2.90	-0.87	-4.43	-2.50	-59.31	-64.13	8.66
Indonesia	-1.11	-4.07	0.18	3.80	-55.61	-69.14	-7.09
Italy	-1.32	-1.77	-3.26	0.06	-49.54	-56.51	3.85
Japan	-0.78	-0.61	-1.56	-0.27	-60.01	-66.01	5.28
S.Korea	-1.19	-0.81	-4.53	0.73	-56.10	-64.30	12.60
Mexico	-3.08	-1.14	-9.17	-1.35	-65.91	-71.34	8.76
Netherlands	-1.12	-3.93	-0.78	3.94	-60.96	-76.82	-3.81
New Zealand	-3.01	-2.12	-7.91	-0.27	-59.98	-74.36	5.00
Norway	-0.68	-1.36	-1.51	0.97	-52.92	-65.61	0.60
Peru	-2.12	-1.53	-5.55	0.32	-61.74	-68.65	12.36
Romania	-1.73	-1.18	-5.13	-0.71	-50.07	-51.54	8.77
Russia	-2.03	-0.94	-5.27	-0.99	-56.48	-59.95	11.48
Vietnam	-5.24	-5.05	-11.22	0.38	-59.47	-69.69	6.10
Spain	-1.37	-1.77	-2.98	-0.30	-52.63	-58.61	1.09
Sweden	-1.12	-0.99	2.07	-0.57	-55.73	-62.44	4.50
Egypt	-0.32	-1.50	-0.71	0.58	-51.11	-57.58	-0.03
UK	-1.22	-3.02	-3.00	0.56	-56.47	-69.32	-7.67
USA	0.51	-1.83	0.69	1.69	-55.92	-57.69	-15.54
ROW	-0.88	-4.10	-2.08	2.05	-59.00	-63.41	-5.65

Notes: Each column reports the percentage change in the respective variable. Welfare, wages, and profits are in real terms. The percentage change in real domestic profits is the % change in real profits earned by firms in country n within the domestic market, i.e., $\left(\frac{(Y_{nn}/P_n)^{\text{counterfactual}}}{(Y_{nn}/P_n)^{\text{2015 tariffs}}} - 1\right) \times 100$. Similarly, the percentage change in real export profits is the % change in real profits earned by firms in country n by exporting goods to other countries, i.e., $\left(\frac{(\sum_{i \neq n} Y_{ni}/P_n)^{\text{counterfactual}}}{(\sum_{i \neq n} Y_{ni}/P_n)^{\text{2015 tariffs}}} - 1\right) \times 100$. Changes in import shares are calculated as the % change in the share of imports in total spending.

Table D.6: Global Tariff War (all countries increase tariffs by 50pp), Fixed Markups

	Welfare	Wages	Profits			Import Share	Prices
			Overall	Domestic	Export		
Australia	-2.17	-2.40	-4.33	-0.78	-60.65	-70.62	-0.36
Austria	-4.00	-2.58	-7.63	-2.73	-62.14	-72.65	7.85
Bangladesh	-2.95	-0.31	-10.18	-2.12	-58.95	-69.00	16.28
Belgium	-3.24	-4.58	-6.95	0.71	-56.67	-64.95	4.45
Brazil	-3.83	-2.65	-9.78	1.20	-62.31	-71.00	7.42
China	-1.02	-0.92	-2.27	0.14	-59.29	-69.59	6.89
Denmark	-2.96	-2.71	-6.59	-0.39	-58.68	-66.84	7.53
France	-2.03	-3.44	-4.18	0.08	-47.35	-61.44	-2.82
Germany	-4.06	-3.61	-13.00	3.18	-63.41	-73.25	12.56
Greece	-2.24	-1.77	-5.52	-0.65	-51.83	-52.97	9.70
India	-2.85	-1.05	-4.40	-2.45	-57.45	-62.09	7.23
Indonesia	-1.97	-2.84	-2.82	1.02	-58.97	-75.74	1.01
Italy	-1.31	-1.70	-3.29	0.01	-49.26	-56.19	5.56
Japan	-0.90	-0.62	-1.79	-0.49	-59.72	-65.59	6.73
S.Korea	-1.39	-1.08	-5.28	0.37	-52.87	-61.20	9.84
Mexico	-3.93	-1.62	-11.14	-2.30	-65.81	-70.55	9.47
Netherlands	-2.23	-3.49	-3.91	0.62	-57.91	-73.78	-3.42
New Zealand	-4.14	-3.05	-10.01	-1.41	-60.00	-74.81	8.07
Norway	-0.95	-1.25	-2.40	0.41	-52.40	-62.67	2.48
Peru	-1.95	-1.51	-5.21	0.56	-60.71	-69.07	12.91
Romania	-1.58	-1.09	-5.06	-0.74	-47.90	-50.12	7.32
Russia	-2.03	-1.43	-5.15	-0.88	-52.94	-56.30	7.20
Vietnam	-5.27	-7.03	-9.46	1.21	-53.58	-68.92	1.87
Spain	-1.35	-1.98	-2.96	-0.25	-51.67	-56.91	0.94
Sweden	-1.03	-0.99	-1.97	-0.49	-55.29	-61.81	4.91
Egypt	-0.80	-1.13	-1.68	-0.30	-48.87	-53.74	0.63
UK	-1.75	-5.18	-3.14	0.25	-52.15	-67.09	-8.22
USA	1.27	-2.03	2.10	2.60	-46.80	-62.00	-15.36
ROW	0.72	-4.56	0.71	3.80	-56.92	-62.40	-2.94

Notes: Each column reports the percentage change in the respective variable. Welfare, wages, and profits are in real terms. The percentage change in real domestic profits is the % change in real profits earned by firms in country n within the domestic market, i.e., $\left(\frac{(Y_{nn}/P_n)^{\text{counterfactual}}}{(Y_{nn}/P_n)^{\text{2015 tariffs}}} - 1\right) \times 100$. Similarly, the percentage change in real export profits is the % change in real profits earned by firms in country n by exporting goods to other countries, i.e., $\left(\frac{(\sum_{i\neq n} Y_{ni}/P_n)^{\text{counterfactual}}}{(\sum_{i\neq n} Y_{ni}/P_n)^{\text{2015 tariffs}}} - 1\right) \times 100$. Changes in import shares are calculated as the % change in the share of imports in total spending.

Table D.7: Global Tariff War (all countries increase tariffs by 50pp), Variable Markups, Homogeneous Elasticities across Countries

	Welfare	Wages	Profits			Import Share	Prices
			Overall	Domestic	Export		
Australia	-2.02	-5.61	-7.07	0.57	-43.87	-41.47	11.06
Austria	-6.27	-18.79	-19.04	1.24	-42.86	-31.23	15.55
Bangladesh	-8.62	-19.95	-20.13	2.73	-44.69	-32.85	16.95
Belgium	-9.49	-24.49	-26.58	2.44	-44.51	-26.22	21.63
Brazil	-1.63	-4.33	-5.13	0.69	-43.08	-41.51	11.07
China	-0.90	-4.14	-3.91	1.12	-42.06	-41.06	8.64
Denmark	-9.54	-24.01	-26.38	3.88	-44.89	-28.08	21.45
France	-3.06	-9.44	-11.18	1.31	-42.39	-37.33	12.98
Germany	-3.42	-13.74	-13.33	4.10	-43.19	-36.14	14.01
Greece	-4.10	-11.15	-13.29	0.57	-42.66	-35.30	14.52
India	-1.97	-5.17	-6.14	0.95	-43.49	-41.13	12.10
Indonesia	-0.79	-15.01	-6.14	6.67	-39.72	-38.24	7.96
Italy	-1.73	-5.94	-7.17	0.93	-42.28	-38.75	12.50
Japan	-1.02	-5.73	-4.69	1.36	-41.22	-39.67	7.68
S.Korea	-7.37	-29.88	-17.44	11.00	-42.45	-27.53	20.78
Mexico	-2.91	-10.62	-9.07	2.44	-43.05	-40.08	10.49
Netherlands	-8.64	-28.91	-23.82	7.46	-42.53	-25.71	21.08
New Zealand	-5.75	-15.38	-16.83	2.05	-43.60	-34.98	16.39
Norway	-6.92	-19.82	-19.24	2.08	-40.50	-30.37	15.08
Peru	-4.18	-6.77	-12.45	0.93	-47.80	-43.10	19.47
Romania	-6.14	-15.79	-18.42	0.81	-43.42	-32.53	16.97
Russia	-2.70	-4.13	-8.03	-0.17	-45.83	-43.04	16.22
Vietnam	-6.30	-14.06	-17.31	1.08	-45.02	-35.57	16.63
Spain	-2.03	-7.54	-8.39	1.94	-43.32	-39.86	12.48
Sweden	-6.87	-22.28	-20.65	4.80	-44.03	-30.27	19.03
Egypt	-4.00	-17.35	-13.08	2.05	-40.01	-31.94	11.37
UK	-2.85	-12.92	-11.00	2.98	-41.03	-36.13	9.90
USA	-0.58	-1.05	-1.98	0.10	-47.27	-50.32	14.11
ROW	-1.17	-2.68	-4.56	0.54	-46.01	-44.86	13.77

Notes: Each column reports the percentage change in the respective variable. Welfare, wages, and profits are in real terms. The percentage change in real domestic profits is the % change in real profits earned by firms in country n within the domestic market, i.e., $\left(\frac{(Y_{nn}/P_n)^{\text{counterfactual}}}{(Y_{nn}/P_n)^{\text{2015 tariffs}}} - 1\right) \times 100$. Similarly, the percentage change in real export profits is the % change in real profits earned by firms in country n by exporting goods to other countries, i.e., $\left(\frac{(\sum_{i\neq n} Y_{ni}/P_n)^{\text{counterfactual}}}{(\sum_{i\neq n} Y_{ni}/P_n)^{\text{2015 tariffs}}} - 1\right) \times 100$. Changes in import shares are calculated as the % change in the share of imports in total spending.

Table D.8: Global Tariff War (all countries increase tariffs by 50pp), Fixed Markups, Homogeneous Elasticities across Countries

	Welfare	Wages	Profits			Import Share	Prices
			Overall	Domestic	Export		
ROW	-1.22	-2.64	-4.64	0.47	-46.12	-45.10	13.64
Australia	-1.98	-5.82	-7.03	0.70	-43.21	-40.68	10.07
Austria	-6.74	-18.67	-19.70	0.73	-43.17	-31.36	15.50
Bangladesh	-9.06	-19.75	-20.91	2.44	-44.96	-32.84	16.94
Belgium	-10.02	-24.33	-27.38	2.15	-44.79	-26.18	21.39
Brazil	-1.68	-4.30	-5.20	0.63	-43.14	-41.59	10.98
China	-0.79	-4.17	-3.69	1.24	-41.72	-41.21	8.23
Denmark	-10.15	-23.62	-27.41	3.15	-45.27	-28.02	21.35
France	-3.34	-9.36	-11.63	1.03	-42.67	-37.29	12.87
Germany	-3.64	-13.63	-13.61	3.78	-43.47	-36.32	13.80
Greece	-4.28	-11.16	-13.53	0.38	-42.77	-35.31	14.27
India	-2.01	-5.15	-6.18	0.88	-43.60	-41.23	11.90
Indonesia	-1.62	-13.97	-7.28	5.28	-39.03	-38.39	7.59
Italy	-1.95	-5.95	-7.53	0.78	-42.41	-38.76	12.28
Japan	-1.37	-5.64	-5.19	0.98	-41.41	-39.66	7.76
S.Korea	-7.32	-29.55	-17.21	10.98	-44.17	-27.13	21.44
Mexico	-3.18	-10.54	-9.49	2.16	-43.32	-40.06	10.85
Netherlands	-9.58	-28.69	-25.10	7.07	-42.77	-25.85	20.53
New Zealand	-6.30	-15.18	-17.81	1.59	-43.83	-34.83	16.51
Norway	-7.65	-19.94	-20.01	1.58	-40.27	-30.67	14.10
Peru	-4.28	-6.74	-12.65	0.84	-47.97	-43.22	19.49
Romania	-6.36	-15.73	-18.71	0.55	-43.58	-32.59	16.75
Russia	-2.86	-4.16	-8.27	-0.33	-46.14	-43.29	16.31
Vietnam	-6.39	-14.13	-17.43	1.02	-44.98	-35.46	16.27
Spain	-2.14	-7.52	-8.52	1.83	-43.44	-39.93	12.21
Sweden	-7.35	-22.08	-21.32	4.30	-44.29	-30.30	18.86
Egypt	-6.03	-16.67	-16.40	-0.09	-40.77	-31.70	12.00
UK	-2.69	-13.48	-10.24	3.58	-39.56	-36.58	8.34
USA	-0.71	-1.02	-2.20	-0.06	-48.23	-50.50	15.34

Notes: Each column reports the percentage change in the respective variable. Welfare, wages, and profits are in real terms. The percentage change in real domestic profits is the % change in real profits earned by firms in country n within the domestic market, i.e., $\left(\frac{(Y_{nn}/P_n)^{\text{counterfactual}}}{(Y_{nn}/P_n)^{\text{2015 tariffs}}} - 1\right) \times 100$. Similarly, the percentage change in real export profits is the % change in real profits earned by firms in country n by exporting goods to other countries, i.e., $\left(\frac{(\sum_{i \neq n} Y_{ni}/P_n)^{\text{counterfactual}}}{(\sum_{i \neq n} Y_{ni}/P_n)^{\text{2015 tariffs}}} - 1\right) \times 100$. Changes in import shares are calculated as the % change in the share of imports in total spending.

Table D.9: Global Tariff War (all countries increase tariffs by 50 pp), Homogeneous Elasticities across Countries and Sectors

	Variable Markups	Fixed Markups	Pro-Competitive Gains
	Welfare	Welfare	
Australia	-1.10	-1.16	-0.07
Austria	-4.00	-4.68	-0.68
Bangladesh	-5.56	-5.77	-0.20
Belgium	-5.69	-6.16	-0.47
Brazil	-1.27	-1.29	-0.02
China	-0.86	-0.87	-0.01
Denmark	-5.78	-6.27	-0.50
France	-1.71	-1.76	-0.05
Germany	-2.34	-2.40	-0.06
Greece	-1.46	-1.60	-0.14
India	-1.31	-1.40	-0.08
Indonesia	-2.29	-2.66	-0.37
Italy	-0.86	-0.94	-0.08
Japan	-0.98	-1.08	-0.09
S.Korea	-3.54	-3.75	-0.21
Mexico	-1.74	-1.87	-0.13
Netherlands	-6.29	-6.74	-0.45
New Zealand	-3.23	-3.59	-0.36
Norway	-3.37	-3.81	-0.44
Peru	-2.16	-2.21	-0.05
Romania	-2.19	-2.37	-0.18
Russia	-1.05	-1.07	-0.02
Vietnam	-4.34	-4.46	-0.12
Spain	-1.29	-1.35	-0.06
Sweden	-3.67	-4.49	-0.82
Egypt	-2.78	-3.76	-0.98
UK	-1.71	-1.87	-0.16
USA	-0.43	-0.44	-0.01
ROW	-0.78	-0.82	-0.04

Notes: This table summarizes the results of the main counterfactual, when all upper-tier demand elasticities are set equal to the value estimated for the U.S. and all lower-tier demand elasticities equal to the median lower-tier demand elasticity estimated for the U.S.. Pro-competitive gains are computed as the difference in the welfare change between the fixed- and the variable-markup case. All values are reported as a percentage, i.e., a value of 1.2 refers to a change in the respective variable by 1.2 percent.

Table D.10: Global Tariff War (all countries increase tariffs by 50 pp), Homogeneous Elasticities across Countries and Sectors (lower-tier elasticity = 10.5)

	Variable Markups	Fixed Markups	Pro-Competitive Gains
	Welfare	Welfare	
Australia	-0.51	-1.72	-1.22
Austria	-1.76	-2.52	-0.76
Bangladesh	-1.59	-1.67	-0.07
Belgium	-1.43	-2.62	-1.19
Brazil	-3.64	-2.69	0.96
China	-0.77	-0.78	-0.01
Denmark	-1.30	-2.12	-0.82
France	-0.84	-1.91	-1.07
Germany	-2.97	-4.26	-1.29
Greece	-0.20	-0.76	-0.57
India	-0.74	-0.67	0.06
Indonesia	-1.70	-2.46	-0.77
Italy	-0.82	-0.86	-0.04
Japan	-0.19	-0.38	-0.19
S.Korea	-0.44	-1.06	-0.62
Mexico	-0.60	-0.81	-0.21
Netherlands	-2.20	-2.79	-0.58
New Zealand	-1.44	-2.60	-1.16
Norway	-0.32	-0.63	-0.30
Peru	-3.04	-3.34	-0.30
Romania	-0.32	-0.44	-0.12
Russia	-1.42	-2.14	-0.72
Vietnam	-3.32	-6.60	-3.28
Spain	-0.31	-0.60	-0.29
Sweden	-1.72	-2.02	-0.29
Egypt	-0.47	-0.71	-0.24
UK	-1.28	-2.22	-0.94
USA	-0.40	-0.36	0.04
ROW	-4.06	-3.01	1.05

Notes: This table summarizes the results of the main counterfactual, when all upper-tier elasticities are set equal to the value estimated for the U.S. and all lower-tier elasticities equal to 10.5 (as in Edmond, Midrigan and Xu, 2015). Pro-competitive gains are computed as the difference in the welfare change between the fixed- and the variable-markup case. All values are reported as a percentage, i.e., a value of 1.2 refers to a change in the respective variable by 1.2 percent.

Table D.11: Global Tariff War (Changes in Trade Matched across Models)

	Variable Markups		Fixed Markups		Pro-Competitive Gains
	Welfare	Imports	Welfare	Imports	
Australia	-1.27	-71.07	-2.28	-71.84	-1.01
Austria	-3.55	-75.42	-4.35	-75.12	-0.79
Bangladesh	-3.05	-68.82	-3.25	-69.00	-0.2
Belgium	-2.89	-66.09	-3.36	-66.12	-0.47
Brazil	-3.72	-70.15	-3.65	-69.26	0.07
China	-1.43	-70.29	-1.08	-71.06	0.35
Denmark	-2.61	-69.08	-3.25	-69.5	-0.64
France	-1.78	-64.69	-2.33	-64.47	-0.56
Germany	-3.77	-72.84	-4.05	-73.25	-0.28
Greece	-2.21	-53.17	-2.34	-52.97	-0.13
India	-2.91	-64.13	-2.96	-63.32	-0.05
Indonesia	-1.15	-69.14	-1.55	-70.4	-0.40
Italy	-1.32	-56.51	-1.3	-56.19	0.01
Japan	-0.78	-66.01	-0.91	-65.59	-0.13
S.Korea	-1.18	-64.3	-1.5	-63.98	-0.32
Mexico	-3.09	-71.34	-4.05	-71.67	-0.97
Netherlands	-1.12	-76.82	-2.51	-76.52	-1.39
New Zealand	-3.01	-74.36	-4.15	-74.81	-1.14
Norway	-0.7	-65.61	-1.12	-65.42	-0.41
Peru	-2.12	-68.65	-2.00	-69.07	0.12
Romania	-1.86	-51.54	-1.96	-51.25	-0.10
Russia	-2.03	-59.95	-2.25	-59.88	-0.23
Vietnam	-5.24	-69.69	-5.51	-70.1	-0.28
Spain	-1.36	-58.61	-1.36	-57.99	-0.01
Sweden	-1.12	-62.44	-1.11	-63.04	0.02
Egypt	-0.13	-57.58	-0.88	-57.31	-0.75
UK	-1.22	-69.32	-1.95	-68.61	-0.73
USA	0.51	-57.69	1.22	-57.51	0.71
ROW	-0.89	-63.41	0.64	-63.7	1.53

Notes: This table summarizes the results of the main counterfactual when all changes in imports in the fixed and variable-markup model are restricted to be equal, as described in the main text. Pro-competitive gains are computed as the difference in the welfare change between the fixed- and the variable-markup case. All values are reported as a percentage, i.e., a value of 1.2 refers to a change in the respective variable by 1.2 percent.

Table D.12: Global Tariff War (all countries increase tariffs by 50pp), Variable Markups, Multinationals

	Welfare	Wages	Profits			Prices
			Overall	Domestic	Export	
ROW	-0.75	-4.10	-2.09	1.91	-58.66	-5.62
Australia	-1.65	-1.26	-3.91	-0.01	-16.54	-0.19
Austria	-4.79	-1.98	-8.20	-2.30	-19.65	8.90
Bangladesh	-2.72	-0.56	-9.79	-1.83	-61.91	19.85
Belgium	-4.97	-4.43	-8.38	1.15	-14.95	3.31
Brazil	-3.68	-2.26	-11.11	0.82	-41.72	6.58
China	-1.39	-0.78	-3.39	-0.38	-46.52	6.36
Denmark	-4.77	-2.44	-8.76	0.20	-18.30	7.61
France	-3.57	-2.28	-6.49	0.24	-13.06	0.58
Germany	-7.55	-3.00	-15.25	2.87	-22.35	9.67
Greece	-1.89	-1.87	-5.47	-0.48	-43.26	8.82
India	-2.81	-0.87	-4.54	-2.52	-47.07	8.69
Indonesia	-1.13	-4.14	0.42	3.92	-43.90	-6.97
Italy	-1.66	-1.76	-3.94	0.01	-23.17	3.84
Japan	-2.05	-0.61	-3.48	-0.28	-17.49	5.31
S.Korea	-2.10	-0.81	-6.74	0.71	-23.65	12.64
Mexico	-3.56	-1.15	-10.61	-1.46	-33.55	8.80
Netherlands	-2.51	-3.93	-3.01	3.74	-5.40	-3.84
New Zealand	-3.00	-2.12	-8.21	-0.27	-32.69	5.02
Norway	-1.64	-1.39	-3.10	0.91	-9.86	-0.32
Peru	-1.71	-1.53	-5.65	0.16	-60.05	12.37
Romania	-1.43	-1.42	-5.19	-0.73	-49.34	9.13
Russia	-1.88	-0.94	-5.61	-0.98	-40.75	11.48
Vietnam	-4.31	-5.05	-10.87	0.24	-57.61	6.13
Spain	-1.36	-1.74	-3.24	-0.32	-20.63	1.05
Sweden	-2.66	-0.99	-4.13	-0.61	-15.45	4.51
Egypt	-0.02	-1.29	-0.39	0.75	-47.35	-4.19
UK	0.14	-3.01	-0.43	0.29	-1.31	-7.66
USA	1.65	-1.83	2.66	1.44	8.89	-15.51

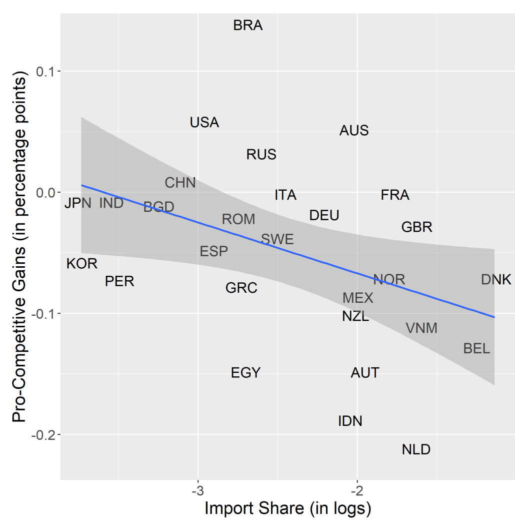
Notes: This table summarizes the results in the presence of multinational firms. Each column reports the percentage change in the respective variable. Welfare, wages, and profits are in real terms. The percentage change in real domestic profits is the % change in real profits earned by firms in country n within the domestic market, i.e., $\left(\frac{(Y_{nn}/P_n)^{\text{counterfactual}}}{(Y_{nn}/P_n)^{\text{2015 tariffs}}} - 1\right) \times 100$. Similarly, the percentage change in real export profits is the % change in real profits earned by firms in country n by exporting goods to other countries, i.e., $\left(\frac{(\sum_{i\neq n} Y_{ni}/P_n)^{\text{counterfactual}}}{(\sum_{i\neq n} Y_{ni}/P_n)^{\text{2015 tariffs}}} - 1\right) \times 100$.

Figure D.1: Profit Shifting and Welfare Changes across Countries (Fixed Markups and Cross-Country Homogeneous Elasticities)

(a) Welfare and Markups (b) Welfare and Elasticities

Notes: Panel (a) plots the change in welfare associated with a global trade war in which tariffs are raised by 50 percentage points in the fixed-markup model with homogeneous demand elasticities, where we assume all countries share the same lower- and upper-tier elasticities of substitution as in the U.S. The x-axis shows corresponding changes in the aggregate markup. Panel (b) plots the change in welfare against the difference in the trade-weighted average inverse demand elasticity of imports versus that of exports at the HS2 level.

Figure D.2: Pro-competitive Effects and Import Shares (Elasticities estimated via Fajgelbaum et al. (2020))



Notes: The y-axis in this plot reports the pro-competitive gains (in percentage points), as measured as the difference in the welfare change under fixed versus variable markups associated with a global trade war in which all tariffs are raised by 50 percentage points. The x-axis reports each country's imports as a fraction of total spending.