Profit Shifting, Import and Export Markups, and the Gains from Trade*

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Abstract: This paper develops a multi-sector, multi-country model of international trade and profit shifting which embeds imperfect product markets and markups into Eaton and Kortum (2002)'s Ricardian trade model. Within a country, producers in different sectors face different demand elasticities, and therefore, charge different markups. Moreover, markup distributions for both imports and exports are allowed to vary across countries. We first show theoretically that the gains from trade can depend crucially on the markup distribution for imported goods versus that for exported goods. To then bring the model to the data and to quantify the markup distributions for imports and exports, we estimate both trade elasticities and a rich set of country- and industry-specific import demand elasticities for over 120,000 distinct sector-country pairs and incorporate them into our structural model. We find that cross-country heterogeneities in the markup distribution for exports and imports are an important determinant of the gains from trade and especially the welfare losses from tariffs; By taking markups into account, these losses are up to three times larger (smaller) for net exporters (importers) of high-markup products. Finally, we apply our model to the recent U.S.-China trade war and show that the U.S. experienced significantly higher welfare losses from the tariff war once markups and profit shifting are taken into account, while China slightly benefited overall.

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1 Introduction

The international distribution of firm profits is arguably one of the most controversial aspects of globalization in recent years and particularly firms from richer economies are often blamed for significant profit shifting away from developing countries. Further, as the role of market power across the world is becoming more and more important and predominantly large firms engage in trade, such issues are likely to become even more relevant in the future. Surprisingly, however, relatively little is known about how important such profit shifting is quantitatively. While there has been previous work that has provided initial predictions on the extent of profit shifting, such studies have either not accounted for a significant extent of sectoral heterogeneity in profits and markups, or did not consider the importance of firm heterogeneity.

In this paper, we fill this gap and develop a quantitative model of international trade and profit shifting in which countries specialize in sectors with heterogeneous markups and profits. To do so, we first incorporate imperfect competition and markups into a multi-sector version of Eaton and Kortum (2002)'s (EK, hereafter) Ricardian trade model. The benefit of this approach is that it allows us to determine and quantify how sectoral variation in markups and trade elasticities, and each country's industrial specialization matter for the gains from trade, while still being able to tractably solve the model in changes analogously to the exact hat algebra employed in Caliendo and Parro (2015).

In order to rationalize markups in the context of the EK model we assume that production technology is proprietary, and slightly alter the timing of the production process. Specifically, we assume that each producer needs to pay (at least part of) the production cost upfront before producing the good. In this case, even though each variety is sourced from the lowest-cost supplier across the world as in EK, this lowest-cost supplier is able to charge the optimal Dixit-Stiglitz markup over its marginal cost and has hence a certain degree of market power, which is determined by the elasticity of substitution σ between varieties. Based on this assumption we develop a multi-sector version of EK which features imperfect competition and country- and sector-specific markups and allows us to study profit shifting both theoretically and empirically.

We first study the determinants of profit shifting theoretically and highlight the importance of both the elasticity of substitution σ, as well as the extent of heterogeneity in firm productivities within sectors. Intuitively, a trade liberalization not only lowers prices, but it also shifts profits of producing high-markup varieties toward the country that has a comparative advantage in producing high-markup products and away from other countries. This profit-shifting channel will hence amplify the gains from trade for countries which are particularly productive in high-markup sectors, but reduce them in other countries. We show that this channel will be particularly important when productivity differentials between countries are small, i.e., the corresponding trade elasticity is high.

In order to bring the model to the data, we estimate both the elasticity of substitution σ and the extent of sectoral variation in firm productivities, θ, for the universe of 6-digit HS product categories for a sample of 30 countries. This not only allows us to determine to what extent countries specialize in high- versus low-markup goods, but also how this varies across markets. In order to estimate the elasticity of substitution across countries and sectors we employ a large-scale application of Soderbery (2015) and estimate about 120,000 distinct sector- and country-specific elasticities σ. Further, we estimate sector-specific trade elasticities θ analogously to Caliendo and Parro (2015) by using detailed information on trade flows and tariffs.

Based on our estimates, we first document considerable variation in terms of the extent to which countries both import and export high- versus low-markup goods. Specifically, we find that rich economies tend to import on average higher-markup goods than poorer economies. The average inverse demand elasticity of goods imported by the U.K., Germany, and Japan, for example, ranges between 0.45 and 0.49 compared to 0.36 in India and 0.38 in China. On the other hand, richer countries also tend to export higher-markup goods than poorer countries, and the average inverse demand elasticity of exports equals, for example, between 0.35 and 0.37 for China, Mexico and Vietnam, while it is around 0.42 for Belgium and Canada. Taken together, we find considerable variation in the difference in markups between imports and exports across countries and that this gap is moderately increasing in a country's income per capita. Exports of Canada, Belgium, and Vietnam for example are significantly higher-markup goods than their imports while the opposite is true for Norway, the U.K., and Germany.

To evaluate how the observed sectoral specialization shapes each country's welfare consequences of trade, we analyze several counterfactual tariff scenarios under both perfect and imperfect competition to highlight and measure the importance of profit shifting. We find that the gains from specializing in high-markup goods are substantial. In a scenario in which tariffs are raised by 20 percentage points in each country, welfare losses in the case of perfect competition range from about 1.5% in smaller economies to e.g. 0.3% in the United States. The introduction of imperfect competition and heterogeneous markups in some cases more than triples this welfare loss, even though the changes in trade volumes remain almost the same. Canada and Belgium for example, due to a strong asymmetry between exports relative to imports of high-markup goods would experience welfare losses of more than 4.8% compared to 1.5% and 1.8%, respectively, in the perfect competition case. On the other hand, welfare losses in countries like the U.K. and Norway are higher under perfect competition, since these countries tend to specialize in the production of lower-markup goods.

More generally, we show that there is a clear positive relationship between the country-specific difference in the inverse demand elasticity between imports and exports and the country's gains from a global tariff war. This suggests that this statistic is largely sufficient in explaining the degree to which countries benefit from profit shifting. Noticeably, we also find that profit shifting can be large enough for a small group of countries to actually benefit in a global tariff war. Specifically, while most countries lose from a global tariff war, we find that Germany, the U.K., and Japan would experience moderate welfare gains in a global tariff war due to more intensely importing than exporting high-markup goods. Further, profit shifting can amplify the implications of unilateral tariff increases: With a unilateral 20 percentage points increase in tariffs, the U.S. for example would generate a welfare gain of 0.264% in the baseline model compared to only 0.158% under perfect competition. Interestingly, we find that profit shifting also appears to be quantitatively more important for the welfare effects of tariffs and trade wars than for the gains from trade. While the latter differs by at most up to 30% from the perfect competition case, the welfare implications of global tariffs are amplified by a factor of 3 for some countries.

We also find that the assumption of homogeneous import demand elasticities across countries, i.e., by using U.S.-based estimates for each sector, can result in misleading predictions. While this assumption has little impact on the results in a setting with perfect competition, it is quantitatively important in a setting with profit shifting. First, we find that the magnitude of the largest observed welfare losses from a global trade war almost doubles with 2.7% in the homogeneous elasticity case and 5.0% in the baseline model. Further, a homogeneous elasticity model would predict positive gains from a global tariff war for a range of developing countries, such as Vietnam, Indonesia, and Romania. We show that by appropriately allowing for country-specific elasticities of substitution, this result disappears, as industry-specific σ's are significantly higher in these countries than in developed nations.

Finally, to highlight the empirical relevance of our framework and given its importance especially for tariff wars, we use our model to re-evaluate the implications of the 2018-19 trade war between the U.S. and China on both countries as well as third parties. We first document that, while the imposed tariffs were fairly uniformly distributed across sectors, the average markup of the industries on which the U.S. imposed tariffs was considerably smaller than that for China, due to differences in the product mix of China's exports versus that of its imports. Consequentially, U.S. tariffs were predominantly imposed on comparably low-markup goods, while China retaliated disproportionately in high-markup sectors. We then determine how each country's specialization pattern in goods with heterogeneous markups affects welfare losses incurred during the trade war. Interestingly, we find that U.S. welfare losses are significantly larger in a setting with imperfect competition and equal close to 0.1 % compared to 0.04% under perfect competition. In addition, China actually slightly benefited from the trade war overall. This result is due to U.S. tariffs having less favorable implications for profit shifting compared to China's tariffs, which provide large benefits to Chinese companies in high-markup sectors. We show that a counterfactual scenario in which the U.S. instead uses tariffs on high-markup goods, while China imposes tariffs on low-markup goods, could have resulted in nontrivial welfare gains of up to 0.07% for the U.S. and 0.1% losses for China.

Our paper makes several contributions to the existing literature. First, by incorporating imperfect competition and markups into a multi-sector version of Eaton and Kortum (2002), we contribute to the literature on quantitative multi-sector trade models (e.g., Costinot, Donaldson and Komunjer (2012); Arkolakis, Costinot and Rodríguez-Clare (2012); Ossa (2015)). This approach allows us to study the consequences of imperfect competition as in Melitz (2003) as well as to tractably account for a distribution of firm productivities as in Eaton and Kortum (2002) in a unified framework. Importantly, it also permits solving the model in changes, à la Dekle, Eaton and Kortum (2008), analogously to the exact hat algebra employed in Caliendo and Parro (2015).[1]

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), and Lashkaripour and Lugovskyy (2018)). We contribute to this literature by explicitly quantifying how each country's specialization pattern in goods with heterogeneous markups affects welfare and the gains from trade and we show intuitively that the net profits a country receives significantly shape its gains from trade. Further, in contrast to Ossa (2014), we study rent shifting in a setting with within-sector productivity heterogeneity and cross-country heterogeneity in markups. Our paper also differs from Lashkaripour and Lugovskyy (2018), as we allow markups and profits to be both sector- and market-specific which has important implications for the gains from trade.[2] To the best of our knowledge, our paper is also the first one that provides a detailed and rigorous assessment of how variation in σ and θ across sectors jointly determine the welfare implications of trade within sectors and overall. Importantly, even though firm-level markups are not variable in our framework, our model does also not fall into the class of models discussed in Arkolakis, Costinot and Rodríguez-Clare (2012), since the share of profit is generally not constant in our framework.

[1]See also Ossa (2014).

[2]While his focus is quite different, Lashkaripour (2020) also documents cross-country and cross-industry heterogeneity in export markups; There are no profits, however, in his paper since he assumes free entry.

Third, our paper is related to the literature on the estimation of trade and substitution elasticities (see e.g. Feenstra (1994), Broda and Weinstein (2006), Simonovska and Waugh (2014), Soderbery (2015), and Caliendo and Parro (2015)). In contrast to these studies, we estimate both elasticities for the universe of 6-digit HS product categories for a considerable sample of 30 countries, which not only allows us to determine to what extent countries specialize in high- versus low-markup goods, but also how this varies across markets. We show that using U.S.-based elasticities of substitution for each country leads to misleading results that are for example inconsistent with the observation that richer countries tend to specialize in higher-quality and markup goods.

Finally, our paper contributes to the literature on the U.S.-China trade war of 2018 and beyond (see e.g. Fajgelbaum et al. (2020) and Amiti, Redding and Weinstein (2019)). We document the novel observation that the tariffs that the U.S. and China imposed vary systematically in terms of markups which makes their impact significantly more complex. Further, we find that welfare predictions in a setting with markup-heterogeneity are markedly different from those in the perfect competition case, with the result that China may have slightly benefited from the trade war. We are unaware of other work that quantifies the importance of profit shifting in trade wars and how sectoral specialization related to markups and industry competitiveness can generate asymmetric welfare losses and gains in trade conflicts.

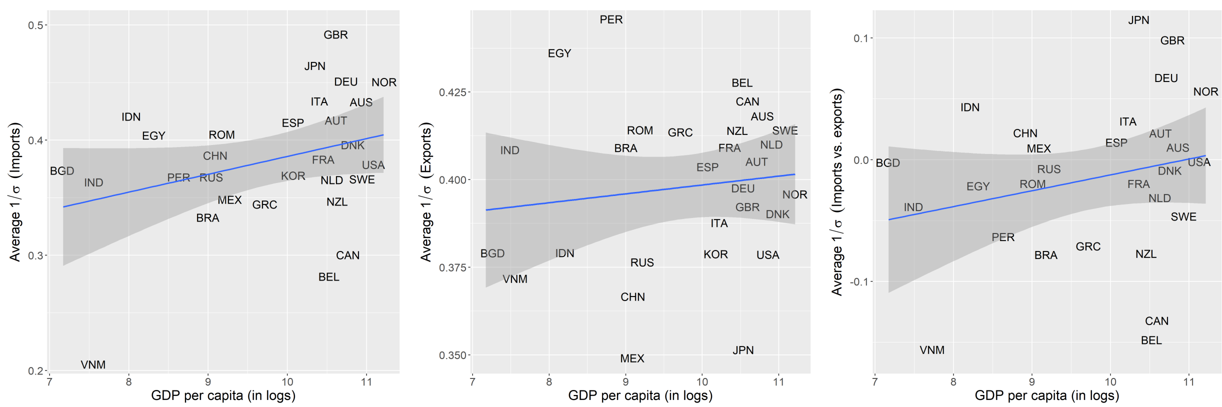
The rest of the paper is organized as follows. Section 2 documents the cross-country heterogeneity in import demand elasticities to motivate the paper. Section 3 develops a quantitative multi-sector trade model with imperfect product markets and sector- and country-specific markups. Section 4 illustrates the main mechanism of the paper using a simplified 2-country, 2-sector model. Section 5 describes the data and the procedure to estimate import demand elasticites and trade elasticities. To show the qualitative and quantitative relevance of profit shifting, Section 6 performs several counterfactual experiments. Section 7 concludes.

2 Motivation

In this section, we first provide suggestive evidence that the goods which countries export and import vary systematically in terms of their demand elasticity and hence in their optimal markups. Specifically, we show that richer countries on average tend to export and import higher-markup goods while the opposite is true for poorer economies.

As described in more detail in Section 5, we begin by estimating the demand elasticity for each of several thousand categories of goods (sectors, hereafter), as defined by their 6-digit Harmonized System codes (HS6). To do so, we rely on the procedure originally developed by Feenstra (1994) and refined by Soderbery (2015) and use detailed information on imports for each country during the years between 1995 to 2015. This results in a set of demand elasticities which are allowed to be different for each country to allow for the possibility that traded varieties of each good as well as the demand for them may differ across countries. We then match the resulting sector- and country-specific elasticities to data on imports and exports of each country in 2015.

Figure 1: Average Inverse Demand Elasticity for imports and exports



(a) Imports (b) Exports (c) Imports - Exports

Notes: The left figure plots the average inverse demand elasticity of each country's imports, weighted by trade volume, while the middle figure plots the corresponding averages for exports. The right figure plots the difference between the two. The shaded areas reflect linear fitted lines along with their 95% confidence bands.

Figure 1 summarizes our estimates and plots the average inverse demand elasticities σ for each country's exports and imports, weighted by trade volumes. We report the inverse demand elasticity to ensure that the results are not driven by very large σ in some categories and also, as will become clear in Section 3, because the inverse demand elasticity is closely related to markup and profit per unit in our model. As shown in Figure 1a, we find that richer economies tend to import goods with, on average, lower demand elasticities σ. For the richest economies, the average $1/\sigma$ takes values in the range between 0.45 and 0.49, while the poorest economies we consider, Vietnam, Bangladesh, and India, import goods with an inverse elasticity between 0.2 and 0.37. On the other hand, richer countries also tend to export higher-markup goods than poorer countries do and the pattern we saw for imports is qualitatively similar but slightly less pronounced for exports. Also here for example, exports from Vietnam, Bangladesh and China tend to be on average lower-markup goods compared to those originating in Belgium, Australia, and Canada.

Taken together, we find considerable variation in the difference in markups between imports and exports across countries. Exports of Canada, Belgium, and Vietnam for example are significantly higher-markup goods than their imports while the opposite is true for Norway, the U.K., and China. As shown in Figure 1c, the exports of rich economies still tend to generate higher markups than their imports do, with the difference in the average inverse demand elasticity being 0.07 on average for the 5 richest economies. For poor economies, this number is negative and the 5 poorest economies export goods whose inverse elasticity is on average 0.05 units larger than that of their imports. Overall, we find that the extent to which exports and imports differ in terms of markups, varies greatly across countries.

Appendix Tables E.1 and E.2 as well as Tables E.3 and E.4 describe in more detail why our estimates differ across countries. Generally, we find that two main factors explain the patterns shown in Figure 1: First, the product mix of imports and exports differs across countries, with some countries e.g. exporting a greater fraction of low-markup goods relative to other countries. This is for example true for China, which tends to import a greater fraction of higher-markup goods but exhibits larger export shares in low-markup ones. Second, there is a considerable degree of country-product specific variation in demand elasticities, i.e., demand for goods in a given sector is differently elastic in one country compared to another. To show this, Tables E.3 and E.4 computes inverse demand elasticites for imports and exports if we use U.S.-based demand elasticities for all countries. Comparing Tables E.1 and E.3 shows that, for example, the main reason why Belgium's imports tend to be in low-markup goods is that our demand elasticity estimates are comparably large in Belgium's most important import sectors.

A natural question is how the observed specialization of richer economies into higher-markup goods translates into welfare and the gains from trade. In the next section we develop a structural model which allows for sectoral and cross-country heterogeneity in markups to answer this question and to understand how trade affects the distribution of profits and prices across countries.

3 The Quantitative Model

This section develops a general equilibrium model of international trade and profit shifting.

3.1 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.

3.2 Preferences and Demand Schedules

Preferences of the representative agent in country n are given by the following Cobb-Douglas function over all sectors:

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

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 CES aggregate over its sub-sectors:

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

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 between 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 implied by (1), consumers in country n face the following price index:

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

Finally, the composite good $q_n^{j(k)}$ is a CES aggregate over a continuum of varieties ω, each sourced from the lowest-cost supplier across the world:

$$q_n^{j(k)} = [\int r_n^{j(k)}(\omega)^{\frac{\sigma_n^{j(k)}-1}{\sigma_n^{j(k)}}} d\omega]^{\frac{\sigma_n^{j(k)}}{\sigma_n^{j(k)}-1}}, \tag{6}$$

where $r_n^{j(k)}(\omega)$ is the demand for variety ω in sub-sector $j(k)$ in country n, and parameter $\sigma_n^{j(k)}$ measures elasticity of substitution between varieties in sub-sector $j(k)$ in country n. These elasticities are allowed to differ across sub-sectors and countries. We assume that the share of each variety is infinitesimal. Equation (6) implies the following demand function for variety ω of sub-sector $j(k)$ in country n:

$$r_n^{j(k)}(\omega) = (\frac{p_n^{j(k)}(\omega)}{P_n^{j(k)}})^{-\sigma_n^{j(k)}} q_n^{j(k)} \tag{7}$$

where $p_n^{j(k)}(\omega)$ is the price charged in country n by the lowest-cost producer of variety ω in sub-sector $j(k)$ across the world and the CES price index $P_n^{j(k)}$ is defined as

$$P_n^{j(k)} = [\int p_n^{j(k)}(\omega)^{1-\sigma_n^{j(k)}} d\omega]^{\frac{1}{1-\sigma_n^{j(k)}}}. \tag{8}$$

3.3 Trade Frictions

Selling a variety of sub-sector $j(k)$ from country i to country n is subject to an ad valorem tariff $t_{in}^{j(k)}$ and an iceberg cost $d_{in}^{j(k)}$. The existence of the iceberg cost means that in order to deliver one unit of a variety in sub-sector $j(k)$ from country i to country n, country i needs to ship $d_{in}^{j(k)}$ units of this good. For future reference, we define trade frictions as

$$\tau_{in}^{j(k)} = d_{in}^{j(k)}(1 + t_{in}^{j(k)}) \tag{9}$$

and assume that the triangle inequality, $\tau_{ih}^{j(k)}\tau_{hn}^{j(k)} \geq \tau_{in}^{j(k)}$, is satisfied for each combination of countries.[3]

[3] 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; For a list of exception countries, refer to footnote 10 in Feenstra and Romalis (2014).

3.4 Technology and Product Market Structure

Variety ω in sub-sector $j(k)$ in country n is produced using a technology with constant returns to scale and labor as the only factor of production:

$$q_n^{j(k)}(\omega) = z_n^{j(k)}(\omega) l_n^{j(k)}(\omega) \tag{10}$$

where $z_n^{j(k)}(\omega)$ denotes a producer's productivity, and the technology of production is assumed to be proprietary.[4] We follow the probabilistic formulation in EK and Caliendo and Parro (2015) and assume that firm-specific productivities in sub-sector $j(k)$ in country n are drawn from a Fréchet distribution with location parameter $T_n^{j(k)}$ and shape parameter $\theta^{j(k)}$. We assume that productivity draws are independent across firms, sub-sectors, and countries.

Variety ω in sub-sector $j(k)$ in country n is sourced from the lowest-cost producer across the world. Each producer needs to pay the production cost upfront before producing the good. To finance the production cost, producers across the world borrow from a frictionless perfectly competitive international financial market with zero net interest rate.[5] Since the production cost has to be paid upfront, the producer which can deliver the variety ω in sub-sector $j(k)$ to country n with the lowest cost charges the optimal Dixit-Stiglitz markup $\frac{\sigma_n^{j(k)}}{\sigma_n^{j(k)}-1}$ over its marginal cost. Note that even though the price that the lowest-cost producer charges may be larger than some other producers' marginal costs, the other producers do not have an incentive to pay the production cost and enter this market, because there is a threat to these other producers if they enter: these producers know that if they enter, the lowest-cost producer would charge a price below their marginal costs to take over the market, and in this case, those other producers would earn negative profit because they have already paid the production cost. In this pricing game, the unique equilibrium is the one in which the lowest-cost producer charges the optimal Dixit-Stiglitz markup $\frac{\sigma_n^{j(k)}}{\sigma_n^{j(k)}-1}$, and the other producers stay out of the market.[6] Hence, the price of a variety ω in sub-sector $j(k)$

[4] In principle, one could easily extend the model to incorporate input-output linkages as e.g. modeled in Caliendo and Parro (2015). In order to focus on the impact of profit shifting and markup heterogeneity, however, we chose to abstract from this channel which allows us to more directly highlight the determinants and implications of profit shifting. That being said, it is well-known that input-output linkages tend to magnify the welfare implications from trade and the welfare changes we find in our counterfactual analysis will hence be likely even larger than those which we find.

[5] We assume international financial markets are frictionless and perfectly competitive, so the equilibrium net interest rate would be zero.

[6] Rather than assuming that production costs have to be paid upfront, it would be equivalent to assume that firms have to pay an infinitesimal fixed operation cost in order to enter. This cost would ensure that only the lowest-cost producer enters while the small nature of the fixed cost would not alter our equilibrium conditions below.

in country n is

$$p_n^{j(k)}(\omega) = (\frac{\sigma_n^{j(k)}}{\sigma_n^{j(k)} - 1}) \times \min_i \{\frac{w_i \tau_{in}^{j(k)}}{z_i^{j(k)}(\omega)}\} \tag{11}$$

where w_i denotes the wage in country i.

3.5 Trade Shares and Total Income

As Appendix A shows, we can use the price equation (11) along with the properties of Fréchet distribution to derive the price index $P_n^{j(k)}$ in (8) as

$$P_n^{j(k)} = A_n^{j(k)} [\sum_{i=1}^{N} T_i^{j(k)} (w_i \tau_{in}^{j(k)})^{-\theta^{j(k)}}]^{\frac{-1}{\theta^{j(k)}}}, \tag{12}$$

where $A_n^{j(k)}$ is a constant that is proportional to the Dixit-Stiglitz markup $\frac{\sigma_n^{j(k)}}{\sigma_n^{j(k)}-1}$. Let $X_n^{j(k)}$ be total expenditure on sub-sector $j(k)$ in country n, and let $X_{in}^{j(k)}$ be the expenditure in country n spent on sub-sector $j(k)$ goods sourced from country i. Then, using the properties of the Fréchet distribution, one can derive the share of country i in country n's expenditure on sub-sector $j(k)$ as[7]

$$\frac{X_{in}^{j(k)}}{X_n^{j(k)}} \equiv \pi_{in}^{j(k)} = \frac{T_i^{j(k)} (w_i \tau_{in}^{j(k)})^{-\theta^{j(k)}}}{\sum_{h=1}^{N} T_h^{j(k)} (w_h \tau_{hn}^{j(k)})^{-\theta^{j(k)}}} \tag{13}$$

Next, we derive an equation for expenditure $X_n^{j(k)}$. Let I_n denote total income in country n. Given country n's preferences as defined by (1), consumers in n spend a fraction α_n^k of their income on goods produced in sector k. Together with Equation (3), this implies that

$$X_n^{j(k)} = \alpha_n^k I_n (\frac{P_n^{j(k)}}{\mathcal{P}_n^k})^{1-\sigma_n^k}. \tag{14}$$

Income in country n is equal to the sum of workers' wage income, firm profits Y_n, tariff revenue R_n, and the trade deficit D_n:

$$I_n = w_n L_n + Y_n + R_n + D_n, \tag{15}$$

where L_n denotes the labor force in country n. Since, by our definition, country i's expenditure in sub-sector $j(k)$ from country n is given by $X_{ni}^{j(k)} = \pi_{ni}^{j(k)} X_i^{j(k)}$, total revenue of sub-sector $j(k)$ firms in country n from their sale in country i must equal $\frac{1}{1+t_{ni}^{j(k)}} \pi_{ni}^{j(k)} X_i^{j(k)}$.

[7]See Appendix A for more details.

Moreover, since these firms charge a markup of $\frac{\sigma_i^{j(k)}}{\sigma_i^{j(k)}-1}$, total revenue of these firms can be expressed as $\frac{\sigma_i^{j(k)}}{\sigma_i^{j(k)}-1}$ times their total cost. Hence, total profit from selling sub-sector $j(k)$ goods in country i equals $\frac{1}{\sigma_i^{j(k)}(1+t_{ni}^{j(k)})}X_{ni}^{j(k)}$ and total profit Y_n can therefore be written as

$$Y_n = \sum_{k=1}^{K}\sum_{j=1}^{J(k)}\sum_{i=1}^{N} \frac{\pi_{ni}^{j(k)} X_i^{j(k)}}{\sigma_i^{j(k)}(1+t_{ni}^{j(k)})}. \tag{16}$$

In order to derive an expression for tariff revenues, we make use of the fact that imports of country n from i in sub-sector $j(k)$ are equal to $\frac{\pi_{in}^{j(k)} X_n^{j(k)}}{1+t_{in}^{j(k)}}$, which allows us to write tariff revenue R_n as

$$R_n = \sum_{k=1}^{K}\sum_{j=1}^{J(k)}\sum_{i=1}^{N} \frac{t_{in}^{j(k)}}{(1+t_{in}^{j(k)})}\pi_{in}^{j(k)} X_n^{j(k)} \tag{17}$$

Finally, to compute trade deficits, we use that, by definition, total imports minus the trade deficit (left-hand side) must equal total exports (right-hand side):

$$\sum_{k=1}^{K}\sum_{j=1}^{J(k)}\sum_{i=1}^{N} \frac{\pi_{in}^{j(k)} X_n^{j(k)}}{(1+t_{in}^{j(k)})} - D_n = \sum_{k=1}^{K}\sum_{j=1}^{J(k)}\sum_{i=1}^{N} \frac{\pi_{ni}^{j(k)} X_i^{j(k)}}{(1+t_{ni}^{j(k)})} \tag{18}$$

It can then be shown that trade balance (18) implies labor market clearing. Specifically, summing over all sub-sectors $j(k)$ and all sectors k in Equation (14), and using the trade balance allows one to write:

$$w_n L_n = \sum_{k=1}^{K}\sum_{j=1}^{J(k)}\sum_{i=1}^{N} \frac{\pi_{ni}^{j(k)} X_i^{j(k)}}{(1+t_{ni}^{j(k)})} - Y_n = \sum_{k=1}^{K}\sum_{j=1}^{J(k)}\sum_{i=1}^{N} \frac{(\sigma_i^{j(k)}-1)\pi_{ni}^{j(k)} X_i^{j(k)}}{\sigma_i^{j(k)}(1+t_{ni}^{j(k)})} \tag{19}$$

3.6 Equilibrium

Equilibrium Definition Given Frećhet location and shape parameters, $T_n^{j(k)}$ and $\theta^{j(k)}$, elasticities of substitution σ_n^k and $\sigma_n^{j(k)}$, Cobb-Douglas shares α_n^k, labor endowments L_n, iceberg trade costs $d_{in}^{j(k)}$, and ad valorem tariffs $t_{in}^{j(k)}$, an equilibrium is characterized by a set of wages $\{w_n\}_{n=1}^N$ that satisfy equilibrium conditions (4), (12), (13), (14), (15), (16), (17), and (18).

Instead of solving the model in levels, we solve the model in changes using the "exact hat algebra" à la Dekle, Eaton and Kortum (2008). The main advantage of solving the model in relative terms is that we do not need information on the the Frećhet location parameters $T_n^{j(k)}$ and iceberg trade costs $d_{in}^{j(k)}$, which are both challenging to identify empirically. To solve the model, we first define the vector of trade frictions as $\tau \equiv \{\tau_{in}^{j(k)}\}_{i=1,n=1,k=1,j=1}^{N,N,K,J(k)}$ and $\hat{x}$ as $\hat{x} = x'/x$, where x' and x denote a variable under a counterfactual trade friction τ' and the actual trade friction τ, respectively. Making use of this notation allows us to express the equilibrium conditions in changes as follows:

First, we divide the price index (12) under τ' by the one under τ, and then use (13) to remove $T_n^{j(k)}$:

$$\hat{P}_n^{j(k)} = \left[\sum_{i=1}^{N} \pi_{in}^{j(k)} (\hat{w}_i \hat{\tau}_{in}^{j(k)})^{-\theta^{j(k)}}\right]^{\frac{-1}{\theta^{j(k)}}} \tag{20}$$

Then, the expressions for the price index (12) and for trade shares (13) can be combined to write the latter in relative terms:

$$\hat{\pi}_{in}^{j(k)} = \left[\frac{\hat{w}_i \hat{\tau}_{in}^{j(k)}}{\hat{P}_n^{j(k)}}\right]^{-\theta^{j(k)}} \tag{21}$$

Next, we write total expenditure (14) in relative terms

$$\hat{X}_n^{j(k)} = \hat{I}_n \left(\frac{\hat{P}_n^{j(k)}}{\hat{\mathcal{P}}_n^k}\right)^{1-\sigma_n^k} \tag{22}$$

and use Equation (14) to write

$$\hat{\mathcal{P}}_n^{k\ 1-\sigma_n^k} = \frac{\mathcal{P}_n'^{k\ 1-\sigma_n^k}}{\mathcal{P}_n^{k\ 1-\sigma_n^k}} = \frac{\sum_{j=1}^{J(k)} P_n'^{j(k)\ 1-\sigma_n^k}}{\mathcal{P}_n^{k\ 1-\sigma_n^k}} = \frac{1}{\alpha_n^k I_n} \sum_{l=1}^{J(k)} \hat{P}_n^{l(k)\ 1-\sigma_n^k} X_n^{l(k)} \tag{23}$$

Substituting the latter into former delivers[8]

$$X_n'^{j(k)} = \alpha_n^k I_n' \frac{\hat{P}_n^{j(k)\ 1-\sigma_n^k} X_n^{j(k)}}{\sum_{l=1}^{J(k)} \hat{P}_n^{l(k)\ 1-\sigma_n^k} X_n^{l(k)}} \tag{24}$$

[8]The model presented in the main text does not feature intermediate inputs and input-output linkages. However, our model easily extends to the case with intermediate inputs and input-output linkages. In that case, one can for example use the following version of total expenditure equation (14)

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

where the last term is the expenditure share of sub-sector $j(k)$ in sector k in country n, which can be directly inferred from data.

Using the income equation (15), we can then write income under counterfactual trade frictions as follows:

$$I'_n = \hat{w}_n w_n L_n + Y'_n + R'_n + D_n \tag{25}$$

where

$$Y'_n = \sum_{k=1}^{K} \sum_{j=1}^{J(k)} \sum_{i=1}^{N} \frac{\pi'^{j(k)}_{ni} X'^{j(k)}_i}{\sigma^{j(k)}_i (1 + t'^{j(k)}_{ni})} \tag{26}$$

$$R'_n = \sum_{k=1}^{K} \sum_{j=1}^{J(k)} \sum_{i=1}^{N} \frac{t'^{j(k)}_{in}}{(1 + t'^{j(k)}_{in})} \pi'^{j(k)}_{in} X'^{j(k)}_n \tag{27}$$

and we assume that trade deficits remain unchanged. Similarly, the trade balance equation (18) can be used to derive the trade balance under counterfactual trade frictions as

$$\sum_{k=1}^{K} \sum_{j=1}^{J(k)} \sum_{i=1}^{N} \frac{\pi'^{j(k)}_{in} X'^{j(k)}_n}{(1 + t'^{j(k)}_{in})} - D_n = \sum_{k=1}^{K} \sum_{j=1}^{J(k)} \sum_{i=1}^{N} \frac{\pi'^{j(k)}_{ni} X'^{j(k)}_i}{(1 + t'^{j(k)}_{ni})} \tag{28}$$

where trade deficits are again assumed to remain unchanged.

Equilibrium Definition in Relative Terms Given Frećhet shape parameters $\theta^{j(k)}$, elasticities of substitution σ^k_n and $\sigma^{j(k)}_n$, Cobb-Douglas shares α^k_n, total expenditures $X^{j(k)}_n$, trade shares $\pi^{j(k)}_{in}$, labor endowments L_n, relative trade frictions $\hat{\tau}^{j(k)}_{in}$, and ad valorem tariffs $t'^{j(k)}_{in}$, an equilibrium is characterized by a set of relative wages $\{\hat{w}_n\}^N_{n=1}$ that satisfy equilibrium conditions (20), (21), (24), (25), (26), (27), and (28).

3.7 Solving for the Equilibrium

This section briefly explains how we solve for the equilibrium, which is described in detail in Appendix B. Specifically, the equilibrium objects that need to be solved for are relative changes in trade shares $\hat{\pi}^{j(k)}_{in}$, relative changes in wages $\hat{w}_n$, relative changes in prices $\hat{P}^{j(k)}_n$, and counterfactual expenditures $X'^{j(k)}_n$. The procedure to solve for the equilibrium is the following:

i) Start with an initial guess for $\hat{w}_n$.

ii) Compute $\hat{P}^{j(k)}_n$ using equation (20).

iii) Use equation (21) to compute $\hat{\pi}^{j(k)}_{in}$.

iv) Use the system of equations (24)-(27) to solve for counterfactual expenditures $X'^{j(k)}_n$.

v) Update $\hat{w}_n$ until the trade balance equation (28) is satisfied.

3.8 Welfare

We define welfare of the representative consumer in country n as the country's real income, i.e.

$$W_n = \frac{I_n}{\mathcal{P}_n}. \tag{29}$$

Using the definition of total income I_n in equation (15), we can readily decompose the percentage change in welfare into a weighted average of percentage changes in real wages, real profits, real tariff revenues, and real trade deficits:

$$\hat{W}_n - 1 = \left(\frac{\hat{w}_n}{\hat{\mathcal{P}}_n} - 1\right)\frac{w_n L_n}{I_n} + \left(\frac{\hat{Y}_n}{\hat{\mathcal{P}}_n} - 1\right)\frac{Y_n}{I_n} + \left(\frac{\hat{R}_n}{\hat{\mathcal{P}}_n} - 1\right)\frac{R_n}{I_n} + \left(\frac{1}{\hat{\mathcal{P}}_n} - 1\right)\frac{D_n}{I_n} \tag{30}$$

where we again assume that trade deficits remain unchanged, i.e., $\hat{D}_n = 1$. This decomposition is particularly useful when exploring the distributional consequences of a trade policy, since the first three terms represent the welfare change contributions of workers, firm owners, and the government, respectively.[9] We explore this decomposition in detail in our counterfactual experiments.

4 An Illustrative Example

Given the complexity of the baseline model presented above, we first illustrate the main idea and mechanisms we quantify in this paper in a simplified setting with 2 countries and 2 sectors. Sections 5 and 6 then cover in detail how we bring the full model to the data and how the insights from this section apply quantitatively to our main data set.

4.1 Framework

There are two countries in the world, Domestic (D) and Foreign (F). Let asterisk * denote Foreign variables. Each country is endowed with L identical agents who inelastically supply labor in a perfectly competitive labor market. There are two sectors H, L in each countryand

[9] We are assuming that firms are owned by a group of entrepreneurs, rather than workers.

preferences are represented by a Cobb-Douglas function over these two sectors:

$$U = Q_L^{\alpha_L} Q_H^{\alpha_H} \quad ; \alpha_L + \alpha_H = 1 \tag{31}$$

$$U^* = {Q_L^*}^{\alpha_L^*} {Q_H^*}^{\alpha_H^*} \quad ; \alpha_L^* + \alpha_H^* = 1 \tag{32}$$

As in the baseline model, each sector produces a composite good that is a CES aggregate over a unit measure of varieties ν. Sectors differ in their elasticity of substitution between varieties, such that

$$Q_i = (\int q(\nu)^{\frac{\sigma_i - 1}{\sigma_i}} d\nu)^{\frac{\sigma_i}{\sigma_i - 1}} \quad ; i = L, H \tag{33}$$

$$Q_i^* = (\int q^*(\nu)^{\frac{\sigma_i - 1}{\sigma_i}} d\nu)^{\frac{\sigma_i}{\sigma_i - 1}} \quad ; i = L, H \tag{34}$$

and each variety ν is sourced from the lowest-cost supplier across the world.

Each variety is produced using a technology with constant returns to scale and labor as the sole production input. Further, to introduce differences in productivities, we assume that all Domestic producers in both sectors and all Foreign producers in sector L share the same productivity equal to 1, whereas all Foreign producers in sector H produce with productivity $A_H^* > 1$.

Each variety can be produced by either a Domestic or a Foreign producer. The Domestic and Foreign producers of ν compete over prices, and the one with lower marginal cost will sell the good. As we assumed in Section 3, producers need to pay the production cost upfront and have access to a frictionless perfectly competitive financial market. Hence, as discussed above, the winner charges the optimal Dixit-Stiglitz markup $\frac{\sigma_i}{\sigma_i - 1}$.

4.2 Closed Economy

We first assume that both countries are in autarky and solve for both countries' welfare. Let w and w^* denote wages in the Domestic and the Foreign economy, respectively. In this case, total profits earned by Domestic producers in sector i have to equal total revenue minus total cost:

$$\Pi_i = \frac{\sigma_i}{\sigma_i - 1} \frac{w}{A_i} Q_i - \frac{w}{A_i} Q_i = \frac{1}{\sigma_i - 1} \frac{w}{A_i} Q_i = \frac{1}{\sigma_i} \alpha_i I \tag{35}$$

where I denotes total Domestic income and the last equality above uses the fact that the Cobb-Douglas preference structure given by (31) implies that total expenditure on sector i is the fraction α_i of income. Further, since total income I is the sum of wage income plus total profit, it equals

$$I = wL + \frac{\alpha_L I}{\sigma_L} + \frac{\alpha_H I}{\sigma_H} \Rightarrow I = \frac{wL}{1 - (\frac{\alpha_L}{\sigma_L} + \frac{\alpha_H}{\sigma_H})} \tag{36}$$

and we can solve for total income in the Foreign economy in a similar fashion:

$$I^* = w^* L + \frac{\alpha_L^* I^*}{\sigma_L} + \frac{\alpha_H^* I^*}{\sigma_H} \Rightarrow I^* = \frac{w^* L}{1 - (\frac{\alpha_L^*}{\sigma_L} + \frac{\alpha_H^*}{\sigma_H})}. \tag{37}$$

Lastly, to compute welfare in autarky, we need to derive the price indices that the representative consumer faces in each economy. Hence, since all Domestic producers in sector i charge the same price $\frac{\sigma_i}{\sigma_i - 1} w$, the price index that the representative Domestic consumer faces is

$$P = (\frac{\sigma_L}{\sigma_L - 1} w)^{\alpha_L} (\frac{\sigma_H}{\sigma_H - 1} w)^{\alpha_H} \tag{38}$$

and utility of the Domestic representative agent in autarky can be written as

$$U_{aut} = \frac{I}{P} = \frac{\frac{L}{1-(\frac{\alpha_L}{\sigma_L}+\frac{\alpha_H}{\sigma_H})}}{(\frac{\sigma_L}{\sigma_L - 1})^{\alpha_L} (\frac{\sigma_H}{\sigma_H - 1})^{\alpha_H}}. \tag{39}$$

In a similar fashion, utility of the Foreign representative consumer in autarky is

$$U_{aut}^* = \frac{\frac{L}{1-(\frac{\alpha_L^*}{\sigma_L}+\frac{\alpha_H^*}{\sigma_H})}}{(\frac{\sigma_L}{\sigma_L - 1})^{\alpha_L^*} (\frac{\sigma_H}{(\sigma_H - 1) A_H^*})^{\alpha_H^*}}. \tag{40}$$

4.3 Free Trade

We assume that international trade is frictionless and balanced and choose the wage in country D to be the numeraire. Here, we consider an equilibrium in which $1 < w^* < A_H^*$ (below, we parameterize the model such that this is the case in equilibrium). In this equilibrium, country D produces all varieties of sector L only, and country F produces all varieties in sector H only. Hence, country D's income equals wage income plus total profits from producing good L for both Domestic and Foreign markets:

$$I = L + \frac{\alpha_L I}{\sigma_L} + \frac{\alpha_L^* I^*}{\sigma_L} \tag{41}$$

Similarly, country F's income equals wage income plus total profits from producing good H to serve both Domestic and Foreign markets:

$$I^* = w^* L + \frac{\alpha_H I}{\sigma_H} + \frac{\alpha_H^* I^*}{\sigma_H} \tag{42}$$

Since trade has to be balanced, it must be the case that imports (left-hand side) and exports of country D (right-hand side) are equal

$$\alpha_H I = \alpha_L^* I^* \tag{43}$$

which implies that

$$I = \frac{\sigma_L}{\sigma_L - 1} L \tag{44}$$

$$I^* = \frac{\sigma_H}{\sigma_H - 1} w^* L. \tag{45}$$

Therefore, relative income can be written as

$$\frac{I^*}{I} = \frac{\alpha_H}{\alpha_L^*} = \frac{\frac{\sigma_H}{\sigma_H - 1} w^*}{\frac{\sigma_L}{\sigma_L - 1}} \tag{46}$$

where the first equality follows directly from the balanced-trade assumption, and the second equality uses Equations (44)-(45). Equation (46) can then be used to solve for the Foreign wage:

$$w^* = \frac{\alpha_H}{\alpha_L^*} \frac{\frac{\sigma_L}{\sigma_L - 1}}{\frac{\sigma_H}{\sigma_H - 1}} \tag{47}$$

Finally, To compute welfare, we need to first solve for the price indices that the representative consumer in each economy faces. Recall that in this equilibrium, all varieties of sector L are produced by Domestic producers with marginal cost equals 1, and they all charge the same markup $\frac{\sigma_L}{\sigma_L - 1}$. Moreover, all varieties of sector H are produced by Foreign producers with marginal cost $\frac{w^*}{A_H^*}$, which charge a markup of $\frac{\sigma_H}{\sigma_H - 1}$. Therefore, given each country's preferences as defined by (31)-(32), the price indices that the representative consumers in Domestic and Foreign economy face are:

$$P = (\frac{\sigma_L}{\sigma_L - 1})^{\alpha_L} (\frac{\sigma_H}{\sigma_H - 1} \frac{w^*}{A_H^*})^{\alpha_H} \tag{48}$$

$$P^* = (\frac{\sigma_L}{\sigma_L - 1})^{\alpha_L^*} (\frac{\sigma_H}{\sigma_H - 1} \frac{w^*}{A_H^*})^{\alpha_H^*}. \tag{49}$$

We can then use the income equations (44)-(45) and price indices (48)-(49) to derive welfare in both countries:

$$U_{trade} = \frac{I}{P} = \frac{\frac{\sigma_L}{\sigma_L-1}L}{(\frac{\sigma_L}{\sigma_L-1})^{\alpha_L}(\frac{\sigma_H}{\sigma_H-1}\frac{w^*}{A_H^*})^{\alpha_H}} \tag{50}$$

$$U_{trade}^* = \frac{I^*}{P^*} = \frac{\frac{\sigma_H}{\sigma_H-1}w^*L}{(\frac{\sigma_L}{\sigma_L-1})^{\alpha_L^*}(\frac{\sigma_H}{\sigma_H-1}\frac{w^*}{A_H^*})^{\alpha_H^*}} \tag{51}$$

Given the welfare expressions (39)-(40) and (50)-(51), we can derive Gains from Trade for both economies:

$$\frac{U_{trade}}{U_{aut}} = \frac{\frac{\sigma_L}{\sigma_L-1}(1-(\frac{\alpha_L}{\sigma_L}+\frac{\alpha_H}{\sigma_H}))}{(\frac{w^*}{A_H^*})^{\alpha_H}} \tag{52}$$

$$\frac{U_{trade}^*}{U_{aut}^*} = \frac{\sigma_H}{\sigma_H-1}(1-(\frac{\alpha_L^*}{\sigma_L}+\frac{\alpha_H^*}{\sigma_H}))w^{*\ 1-\alpha_H^*} \tag{53}$$

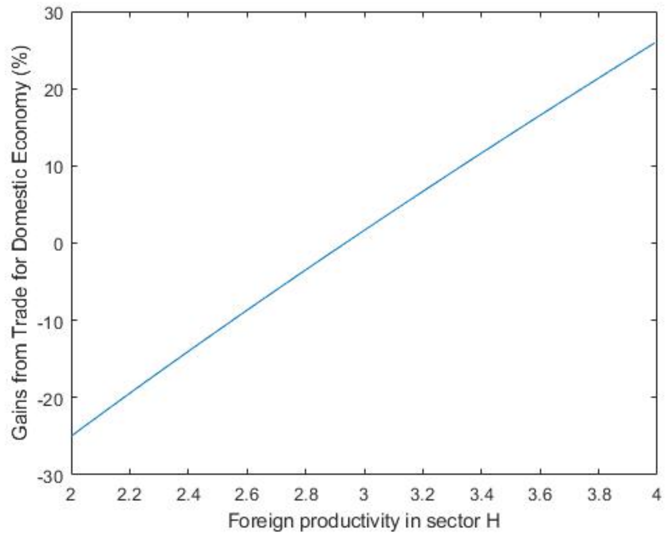
4.4 The Gains from Trade

How important is profit shifting in this setting? We first parameterize the model and set the Cobb-Douglas parameters equal to $\alpha_H = \alpha_H^* = 0.75$ and $\alpha_L = \alpha_L^* = 0.25$. Importantly, we also assume that sector H has a lower elasticity of substitution, so its producers charge higher markups than sector L producers. In particular, we set $\sigma_H = 1.5$ and $\sigma_L = 2$. Below, we explore how the gains from trade vary with Foreign productivity $A_H^* > w^*$. With this parameterization, as discussed above, the Foreign economy specializes in the high-markup sector H while the Domestic one specializes in the lower-markup sector L.

To analyze the welfare consequences of trade, note that there are two potentially competing forces influencing the gains from trade. First, after trade liberalization, countries gain access to cheaper varieties, which raises welfare in both economies. We refer to this mechanism as the price channel in what follows. Second, trade liberalization shifts profits of producing high-markup varieties toward the country that has a comparative advantage in producing high-markup products, which we refer to as the profit-shifting channel. Since with free trade the Foreign economy specializes in producing high-markup varieties, the profit-shifting channel raises welfare in the Foreign economy, while it reduces welfare in the Domestic economy.

Under the parameters we set, country F gains from trade, regardless of its productivity A_H^*. The reason is that for the Foreign economy, the price and profit-shifting channels work in the same direction and raise country F's welfare. More interestingly, however, Figure 2 plots the gains from trade in the Domestic economy as a function of $A_H^* > w^*$. We see that country D may gain or lose from trade depending on the magnitude of A_H^*. The reason for this ambiguity is that for the Domestic economy, the price and profit-shifting channel work

Figure 2: Gains from Trade for the Domestic Economy



Notes: The figure plots the gains from trade in the domestic country depending on Foreign's productivity A_H^* when elasticities vary across sectors ($\sigma_H = 1.5$ and $\sigma_L = 2$).

in opposite directions, and the overall magnitude of gains or losses from trade depends on the relative size of these two competing forces: If productivity A_H^* is "large enough", the welfare gain from the price channel dominates the losses from the profit-shifting channel, and the Domestic economy gains from trade. If, however, country F's productivity is not "large enough", the welfare loss from the profit-shifting channel dominates, and trade hurts country D's welfare.

In summary, the gains from trade depend on the size of the price and profit-shifting channels, which in turn depend on relative productivities across the world as well as whether countries specialize in low- or high-markup products. Which effect dominates and whether or not profit shifting is quantitatively important is therefore largely an empirical question and we use the full quantitative model developed in Section 3 to answer these questions in detail in the next sections.

5 Data and Estimation

5.1 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 a total of 30 countries in the analysis, which account for the vast majority of global trade and represent a mix of richer and poorer economies.[10] In order 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.[11]

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. In order 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.[12] Overall, our final dataset contains 4,111 distinct HS6 sectors.

Both for the counterfactual experiments and for identification of the trade elasticity $\theta^{j(k)}$, 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 HS6 industry for the year 2015 and match it to the dataset. We obtain tariffs imposed by the U.S. and China during the 2018-19 Trade War from the Peterson Institute for International Economics. Specifically, we use information on tariffs which have been imposed in the first 3 waves, i.e., until September 2019. Finally, we infer each country's wage bill by using information on labor income shares as a percentage of GDP as provided by the ILO. Table 1 provides detailed summary statistics of the final dataset.

5.2 Estimation of Trade Elasticities

We estimate trade elasticities $\theta^{j(k)}$ using a large-scale application of the approach developed by Caliendo and Parro (2015). Specifically, using the trade share equation (13), we follow Caliendo and Parro (2015) to show that trade elasticities $\theta^{j(k)}$ can be, under relatively mild

[10]Specifically, we include the following countries: Australia, Austria, Bangladesh, Belgium, Brazil, Canada, China, Denmark, Egypt, France, Germany, Greece, India, Indonesia, Italy, Japan, Mexico, Netherlands, New Zealand, Norway, Peru, Rep. of Korea, Romania, Russian Federation, Spain, Sweden, USA, United Kingdom, Vietnam, and a constructed Rest of the World.

[11]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 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, we 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.

[12]More specifically, the issue is that HS categories can change over time and e.g. in some cases (1) split into multiple new HS codes or (2) several HS codes are merged into one. In those case, to make sure that categories do not cover different goods in one year versus the other, we keep track of these changes and create categories which contain all relevant HS codes. For example, category 722210 splits into 722211 and 722219 in 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 afterwards.

Table 1: Summary Statistics

	Mean	Std. Deviation	N
Imports (in mn. \$)	95.77	16208.68	1646356
Weight (in mn. kg)	28.02	24009.91	1523146
Exp. Share	0.07	0.20	1640866
θ (HS2 level)	5.81	5.71	1646356
σ (HS6 level)	73.14	3520.43	1646356
Wage Bill (in bn. \$)	2637.48	4212.64	1646356
Tariff (MFN, ad valorem)	6.58	21.80	1641733
Tariff (applied, ad valorem)	3.85	18.97	1644034
Tariff - Trade War (U.S., ad valorem)	18.26	9.39	4,111
Tariff - Trade War (China, ad valorem)	19.50	10.44	4,111

assumptions, estimated via equation

$$\ln\left(\frac{X_{ni}^{j(k)} X_{ih}^{j(k)} X_{hn}^{j(k)}}{X_{in}^{j(k)} X_{hi}^{j(k)} X_{nh}^{j(k)}}\right) = -\theta^{j(k)} \ln\left(\frac{\tilde{t}_{ni}^{j(k)} \tilde{t}_{ih}^{j(k)} \tilde{t}_{hn}^{j(k)}}{\tilde{t}_{in}^{j(k)} \tilde{t}_{hi}^{j(k)} \tilde{t}_{nh}^{j(k)}}\right) + \tilde{\epsilon}_{ihn}^{j(k)}, \tag{54}$$

using OLS, where $\tilde{t}_{ni}^{j(k)} = 1 + t_{ni}^{j(k)}$.[13] To estimate this equation, we use data on imports for each country and applied tariffs. Since there are 13 EU member countries in the data set, which all set the same tariffs against other countries, we include only one EU country, Germany, for the estimation. In total, we hence use 18 countries to estimate $\theta^{j(k)}$.

In estimating Equation (54) and also in the counterfactuals, we assume that all 6-digit sectors within a 2-digit industry share the same Frèchet dispersion parameter, and then estimate $\theta^{j(k)}$ separately for each of 95 2-digit sectors.[14] This assumption, for example, implies that productivity is equally dispersed within each automobile category or within each type of produce. For example, we estimate a value of $\theta^{j(k)} = 0.13$ for the HS2 category 87, which summarizes vehicles such as motor cars (e.g. 870322), buses (e.g. 870220), and trucks (e.g. 870422). Our assumption hence implies that θ is equal to 0.13 for each of these 6-digit categories and that productivity dispersion is the same within those sectors. We later explore the sensitivity of our results to this assumption and show explicitly how the results change if e.g. the same $\theta^{j(k)}$ is used across all goods.

Table 2 summarizes our estimates across all sectors. We estimate a median $\theta^{j(k)}$ of 3.69, with the mean across sectors being 3.84. These numbers are in line with Caliendo and Parro

[13] The crucial identifying assumption is that tariffs are orthogonal to $\tilde{\epsilon}^{j(k)}$, which requires that tariff changes can be treated as exogenous after employing Caliendo and Parro (2015)'s triple-differencing strategy.

[14] We make this assumption because estimating trade elasticities separately for each 6-digit HS sector results in quite a few negative $\theta^{j(k)}$, which are inconsistent with theory.

(2015) who find aggregate elasticities between 3.29 and 4.55. As is well known, Caliendo and Parro (2015)'s approach can occasionally result in negative estimates, which are inconsistent with theory. In our data, we estimate a negative θ for about 17% of sectors. In those cases, we instead use the median $\theta^{j(k)}$ for those sectors in the counterfactuals.

Table 2: Distribution of parameter estimates for θ and σ

	Median	1st Quartile	3rd Quartile
θ	3.69	0.17	8.06
σ	Median	1st Quartile	3rd Quartile
Australia	1.93	1.47	3.11
Austria	2.76	1.70	6.31
Bangladesh	2.99	2.06	5.06
Belgium	3.15	1.94	6.73
Brazil	2.58	1.74	4.28
Canada	4.41	2.09	11.13
China	3.05	1.85	6.52
Denmark	2.40	1.67	4.71
France	2.49	1.64	4.98
Germany	2.65	1.70	5.23
Greece	2.27	1.68	3.59
India	3.48	2.08	7.68
Indonesia	2.37	1.70	3.87
Italy	2.10	1.53	3.71
Japan	2.19	1.61	3.65
Rep. of Korea	2.63	1.70	4.65
Mexico	2.64	1.77	4.89
Netherlands	2.45	1.65	4.71
New Zealand	2.70	1.78	4.77
Norway	2.30	1.72	3.38
Peru	2.41	1.80	3.56
Romania	2.48	1.70	4.19
Russia	2.53	1.73	4.38
Vietnam	9.25	3.62	19.55
Spain	2.56	1.76	4.11
Sweden	3.04	1.79	6.73
Egypt	2.19	1.72	3.09
United Kingdom	1.96	1.50	3.34
USA	2.49	1.61	5.99
ROW	2.72	1.58	7.02

Notes: This table provides summary statistics for the parameter estimates of θ and σ. The former is estimated for 2-digit product categories and the latter for 6-digit sectors. The median and quartiles are taken over product categories.

5.3 Estimation of the Elasticities of Substitution

We estimate the elasticity of substitution at both HS6 and HS2 level, separately for each country, using the hybrid estimator method proposed in Soderbery (2015), which is based on the approach developed by Feenstra (1994). This method combines limited information maximum likelihood (LIML) with a constrained non-linear LIML routine and addresses the potential small sample bias and grid search inefficiencies present in previous methodologies.[15]

Specifically, following Broda and Weinstein (2006), this approach assumes that consumption in each composite HS6 good can be written as a CES aggregate over different varieties,

$$q_n^{j(k)} = \left[\int b_n^{j(k)}(\omega)^{\frac{1}{\sigma_n^{j(k)}}} r_n^{j(k)}(\omega)^{\frac{\sigma_n^{j(k)}-1}{\sigma_n^{j(k)}}} d\omega \right]^{\frac{\sigma_n^{j(k)}}{\sigma_n^{j(k)}-1}} \tag{55}$$

where $b_n^{j(k)}(\omega)$ denotes a variety-specific taste shock. Together with the assumption of an upward sloping supply curve, this preference structure implies demand and supply curves of the form

$$\Delta^k ln(s_n^{j(k)}(\omega)) = -(\sigma_n^{j(k)} - 1)\Delta^k ln(p_n^{j(k)}(\omega)) - \xi_n^{j(k)}(\omega) \tag{56}$$

$$\Delta^k ln(p_n^{j(k)}(\omega)) = \left[\frac{\kappa_n^{j(k)}}{1 + \kappa_n^{j(k)}}\right]\Delta^k ln(s_n^{j(k)}(\omega)) + \delta_n^{j(k)}(\omega) \tag{57}$$

where $\kappa_n^{j(k)}$ denotes the inverse export supply elasticity for good $j(k)$, and $\xi_n^{j(k)}(\omega)$ and $\delta_n^{j(k)}(\omega)$ reflect unobservable demand and supply shocks.

Following Feenstra (1994)'s identifying assumption that these demand and supply shocks are orthogonal, i.e., $E[\xi_n^{j(k)}(\omega)\delta_n^{j(k)}(\omega)] = 0$, one can multiply the two shocks to convert the structural equations of demand and supply into one estimation equation

$$\left(\Delta^k ln(p_n^{j(k)}(\omega))\right)^2 = \theta_{1,j(k)}\left(\Delta^k ln(s_n^{j(k)}(\omega))\right)^2 + \theta_{2,j(k)}\left(\Delta^k ln(p_n^{j(k)}(\omega))\right)\left(\Delta^k ln(s_n^{j(k)}(\omega))\right) + u_n^{j(k)} \tag{58}$$

which can be consistently estimated using 2SLS estimation with variety indicators as instru-

[15] 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). Soderbery (2015)'s approach is also consistent with our theoretical framework as the demand side in both settings is derived from CES preferences. One difference is that Broda and Weinstein (2006) and Soderbery (2015) model the supply side in a reduced-form way compared to the more structural approach taken here and allow for an upward-sloping supply curve for varieties. Soderbery (2015)'s framework therefore nests ours, in which the supply curve is horizontal, and controls for any potential endogeneity bias in cases in which this assumption might be violated empirically.

ments.[16]

As described above, we employ bilateral trade data on the HS6 level for the years between 1995 and 2015 and estimate $\sigma_n^{j(k)}$ separately for each sector and country to allow for the possibility that traded varieties of each good as well as the demand for them may differ across countries. We also apply the same methodology to estimate HS2-level elasticities σ_n^k for each country.

Table 2 provides summary statistics and shows the distribution of the estimated import demand elasticities across countries. We estimate σ to be particularly low for Australia, the U.K., Italy, and Japan. On the other end, we estimate comparably large elasticities of substitution for Vietnam, India, Canada, Belgium, and China.

Generally, we find that about 30% of the variation in the inverse σ can be explained by product and importer fixed effects, with about 2/3 of this variation being due to the elasticity of substitution varying across products. This is consistent with the idea in Feenstra (1994) that product categories are differently differentiated and 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 due to varying income levels, which might explain why the median σ is comparably high in the poorer economies Vietnam, India, and China.

Finally, a significant fraction of the variation in the elasticity of substitution is due to country-product-specific factors which suggests the presence of other, unobserved determinants of σ. This may for example be due to the set of varieties that one country imports being quite different compared to those that another country imports due to varying trade partners, product standards, or country-specific tastes. While understanding the exact nature of these factors is beyond the scope of the paper, our model is able to account for such country-product-specific factors in the analysis and can in principle provide insights on how important they are for the gains from trade, overall and across countries.

6 Counterfactual Analysis

In this section, we use the quantitative model developed in Section 3 to study the welfare consequences of different trade policies. In particular, we quantify the welfare implications of a counterfactual global tariff war, the gains from trade (i.e., gains from moving from autarky to the observed trade volumes), and the welfare consequences of the recent U.S.-China tariff

[16] Following Soderbery (2015), we weight varieties by their respective estimated residuals to control for outliers.

war.

To emphasize the role of profit-shifting channel in deriving the welfare consequences of trade, we perform all counterfactual exercises using two versions of our model. The first version is our baseline model described in Section 3. In the second version, we slightly change the technology described in Section 3.4: In particular, we follow the standard perfect competition assumption in Ricardian models (e.g., Eaton and Kortum (2002) and Caliendo and Parro (2015)) and assume that production technology is *common* to all potential producers of each variety (rather than assuming *proprietary* technology in our baseline model). As a result, in this version of the model, the lowest-cost producer of each variety charges a price equal to its marginal cost. In what follows, we call the first version the "baseline model" and the second version the "perfect competition model." Note that these two versions of our model share the exact same equilibrium conditions stated in Section 3.6, except for the fact that profits Y_n are zero in the perfect competition model.

Moreover, to show the importance of incorporating cross-country heterogeneity in the elasticities of substitution, we perform all our counterfactual experiments twice. While in one version we include cross-country heterogeneity in $\sigma_i^{j(k)}$, in the alternative specification we assume that all countries share the same utility function (i.e., the same elasticities of substitution) as in the U.S. Since the latter assumption is common in the literature, this exercise allows us to explore the importance of this assumption in our counterfactual experiments.

Since we solve the model in changes using the "exact hat algebra," we are able to exactly match the observed data in 2015 before performing the counterfactual experiments. To take care of trade deficits, we first set trade deficits to zero, then calibrate both the baseline and the perfect competition models to the observed trade data in 2015. We assume trade deficits remain zero in all counterfactual experiments.[17]

6.1 Welfare Consequences of a Global Tariff War

Baseline vs Perfect Competition Model In the first counterfactual experiment, we consider a global tariff war in which all countries raise their import tariffs by 20 percentage points, across all goods and against all countries. Table 3 reports the results. The first four columns correspond to the baseline model, and the last three columns are associated

[17] In the baseline model, to make sure that outlier elasticities do not govern our counterfactual results, we also winsorized the estimated 2-digit and 6-digit elasticities of substitution from above at 20, and from below at 1.05, to make sure that outlier elasticities do not govern our counterfactual results. However, as a robustness exercise, we also used our baseline model without winsorizing elasticities to perform the global tariff war counterfactual experiment. As Appendix Table E.9 shows, the results are very similar to those in Table 3 below.

with the perfect competition model. Columns "welfare" report the percentage change in welfare. Based on the welfare decomposition (30), we decompose the welfare changes into the percentage change in real wages, real profits, and real tariff revenues, reported in columns "wage", "profit", and "tariff", respectively.[18] As expected, in the perfect competition model all countries lose from the global tariff war. This is the case since in the perfect competition model, a global tariff war reduces real wages in all economies because of an increase in the equilibrium price index. Tariff revenues in all countries rise, but this is not enough to compensate for the decline in real wages.

As shown in Figure 3a, under imperfect competition the welfare consequences of a global trade war are markedly different from those under perfect competition. First, as evident from comparing Figures 3a and 3b, predicted welfare changes are significantly larger in magnitude when we account for profit shifting and range from 0.1 to -5.0 percent compared to only up to -1.8% in the perfect-competition case. Further, the average markup that countries pay (via imports) minus the average markup that countries earn (via exports) has a large predictive power for the welfare results in the baseline model.[19] Countries such as Vietnam, Canada, and Belgium for example experience welfare declines between 2% and 5% while Germany, the U.K. and Japan are only very little affected by such tariffs. Interestingly, these three countries do even slightly gain from this global tariff war since the markups they pay on their imports are much larger than the markups they earn from their exports. Hence, even though all 3 countries have sizable trade shares and would suffer sizable welfare losses from tariffs under perfect competition, tariffs would generate strong gains due to profit shifting.

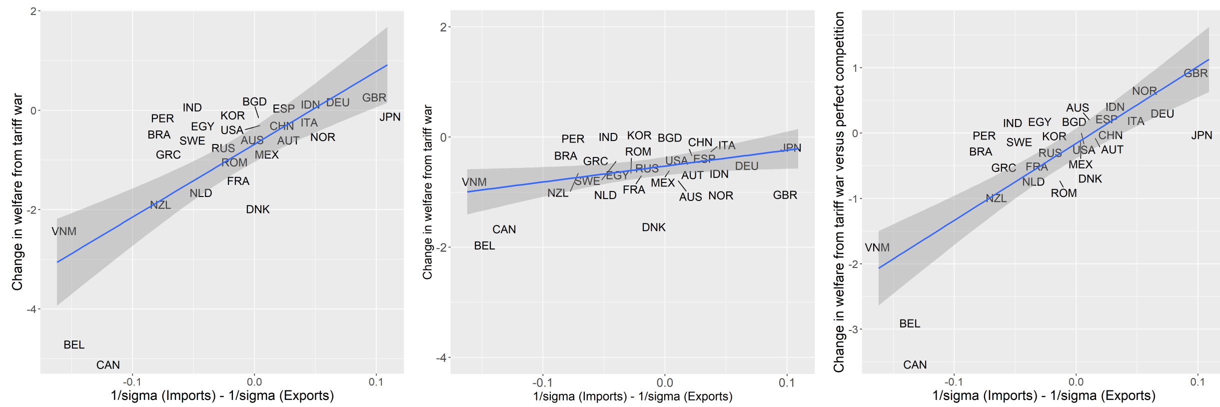
As evident from Table 3, the main reason for this finding is that profits decline much more strongly in other countries, with the consequence that the additional tariff revenue compensates for declines in wages and profits in those 3 countries. For most countries, the changes in wages and tariff revenue in fact largely cancel each other out, with the result that the change in profits is strongly correlated with the change in welfare. Since differences in import and export markups are an important determinant of a country's profits, we therefore find the strong correlation between this markup gap and welfare that is present in Table 3.

Moreover, as Figure 3c shows, the welfare change from this global tariff war in the baseline model versus that in the perfect competition model is increasing in the difference between average import and export markups. As Figure 3c and Table 3 highlight, for countries with low import markups relative to their export markups, the loss from global war is larger in the baseline model relative to the case of perfect competition. For instance, the welfare loss

[18]As noted, we remove trade deficits before doing the counterfactual experiments and assume they remain zero.

[19]Note that in the graph, we show the average inverse demand elasticity, which is positively correlated with the markup.

Figure 3: Welfare Consequences of a Global Tariff War



(a) Baseline Model (b) Perfect Competition (c) Baseline vs. Perfect Comp.

Notes: The horizontal axis in both graphs measures average import markup minus average export markup by a country. The vertical axis in panels (a) and (b) describe percentage changes in welfare when all countries raise all import tariffs by 20 percentage points, using our baseline model. The vertical axis in panel (c) is percentage changes in welfare in our baseline model minus those in the perfect competition model, when all countries raise all import tariffs by 20 percentage points. The shaded areas reflect linear fitted lines along with their 95% confidence bands.

in the baseline model is larger than the welfare loss in the perfect competition setting by almost 3.5 percentage points for Canada, 3 percentage points for Belgium, or 1.6 percentage points for Vietnam.

On the other hand, for countries with high import markups relative to their export markups, the loss from the global war is smaller in the baseline model than under perfect competition. For instance, the welfare loss in the baseline model is almost 1 percentage point smaller for the U.K., 0.4 percentage points for Germany, and 0.5 percentage points for Indonesia and Norway. Indeed, unlike the perfect competition model, the U.K., Germany, and Japan gain from the global tariff war in our baseline model. Finally, for some countries like the U.S., import markups are close to export markups. Hence, for these countries, the welfare consequences of this global tariff war are very similar in the two models.[20]

Appendix Tables E.1 and E.2 as well as Tables E.3 and E.4 show in more detail why we

[20]We also find that the differences between the imperfect and perfect competition case tend to be stronger for smaller economies, and the welfare losses are e.g. significantly larger under imperfect competition for Belgium, Vietnam, and Canada, while the opposite is true for Norway or Egypt. One explanation for this finding is that the average inverse elasticity for these countries is more sensitive to individual product categories as these countries tend to trade a smaller fraction of products than big countries. As a consequence, high or low estimates for σ in larger sectors then translate into higher or lower average values and welfare changes as well. For example, Vietnam imports a comparably large share in HS2 categories 84 and 85, which describe imports of machinery. Since we estimate the elasticity of substitution to be comparably high for corresponding products, the average inverse σ is relatively small for Vietnam overall.

Table 3: A Global Tariff War: welfare changes (%) when all countries raise all tariffs by 20 percentage points

Countries	Baseline Model				Perfect Competition Model		
	welfare	wage	profit	tariff	welfare	wage	tariff
Australia	-0.594	-1.049	-0.516	0.971	-0.795	-1.765	0.969
Austria	-0.601	-0.847	-0.726	0.972	-0.520	-1.492	0.972
Bangladesh	-0.151	-0.164	-0.072	0.085	-0.181	-0.265	0.084
Belgium	-4.854	-2.607	-4.559	2.312	-1.836	-4.204	2.368
Brazil	-0.626	-0.457	-0.415	0.245	-0.465	-0.711	0.246
Canada	-4.968	-2.503	-4.657	2.192	-1.541	-3.790	2.250
China	-0.164	-0.286	-0.136	0.258	-0.195	-0.453	0.258
Denmark	-2.137	-2.396	-2.188	2.447	-1.502	-3.960	2.458
France	-1.271	-1.285	-1.222	1.236	-0.703	-1.945	1.243
Germany	0.021	-0.898	-0.120	1.039	-0.388	-1.424	1.036
Greece	-0.720	-0.433	-0.636	0.349	-0.304	-0.654	0.350
India	-0.160	-0.135	-0.089	0.065	-0.127	-0.192	0.065
Indonesia	-0.021	-0.712	0.074	0.618	-0.527	-1.142	0.614
Italy	-0.080	-0.536	-0.126	0.582	-0.267	-0.848	0.581
Japan	0.026	-0.170	-0.003	0.199	-0.055	-0.255	0.199
Rep. of Korea	-0.244	-0.226	-0.220	0.202	-0.090	-0.292	0.202
Mexico	-0.737	-1.511	-0.852	1.627	-0.614	-2.247	1.632
Netherlands	-1.511	-1.357	-1.558	1.404	-0.899	-2.311	1.412
New Zealand	-1.754	-1.051	-1.584	0.880	-0.657	-1.546	0.889
Norway	-0.389	-1.216	-0.343	1.171	-0.926	-2.092	1.166
Peru	-0.308	-0.207	-0.283	0.182	-0.165	-0.347	0.182
Romania	-0.892	-0.427	-0.959	0.494	-0.159	-0.656	0.496
Russia	-0.666	-0.543	-0.517	0.394	-0.435	-0.829	0.394
Vietnam	-2.574	-1.501	-2.132	1.059	-0.941	-2.017	1.075
Spain	-0.105	-0.334	-0.173	0.403	-0.222	-0.624	0.402
Sweden	-0.465	-0.524	-0.802	0.861	-0.443	-1.305	0.863
Egypt	-0.338	-0.333	-0.217	0.212	-0.384	-0.596	0.212
United Kingdom	0.120	-1.200	0.065	1.255	-0.917	-2.163	1.246
USA	-0.307	-0.336	-0.363	0.392	-0.307	-0.699	0.392
ROW	-0.823	-2.131	-0.871	2.179	-1.440	-3.578	2.138

Notes: The first four columns associate with the baseline model, and the last three columns are associated with the perfect competition model. Columns "welfare" report the percentage change in welfare. Based on the welfare decomposition (30), we decompose the welfare changes into the percentage change in real wages, real profits, and real tariff revenues, reported in columns "wage", "profit", and "tariff", respectively. Numbers are rounded to the nearest thousandth.

find comparably large differences between the 2 models for some countries and not for others. First, as mentioned above, the product mix of imports and exports differs across countries, with some countries e.g. exporting a greater fraction of low-markup goods relative to other countries. This is for example the case for China, which imports a greater fraction of high-markup goods but exhibits greater export shares for low-markup ones and as a consequence experiences smaller welfare losses in the baseline model than it did under perfect competition. Second, there is a considerable degree of country-product specific variation in the elasticity of substitution, i.e. demand for varieties of certain goods is differently elastic in one country compared to another. As evident from Appendix Table E.1, this is e.g. the main reason why Belgium's imports tend to be in low-markup goods, as our estimates predict comparably large elasticities in Belgium's most important import sectors. Since its exports tend to be higher-markup goods, Belgium therefore experiences particularly large welfare losses under imperfect competition.

Interestingly, since both the baseline and perfect competition models share the same trade elasticities $\theta^{j(k)}$, the change in trade volumes is quite similar in the two models. This is evident by observing that the tariff contributions to welfare are very close across the two models.[21] Hence, even conditional on the same changes in trade volumes, the baseline model has quite different implications for welfare consequences of trade, which will become more clear when we compute the gains from trade below. As a result, even though firm-level markups are not variable in our framework, our model does not fall into the class of models discussed in Arkolakis, Costinot and Rodríguez-Clare (2012), since the share of profit is generally not constant in our framework.

Lastly, the global tariff war influences workers and firm owners differently. In countries like Vietnam, Belgium, Canada, and New Zealand with high export markups relative to import markups, declines in profits are generally larger than wage reductions. In countries like the U.K., Japan, Germany, and Norway with high import markups relative to export markups, however, workers experience stronger losses than firm owners. Note that the U.K. is the only country in which firm owners gain from this global tariff war.

The Role of Heterogeneous Elasticities of Substitution To show the importance of incorporating cross-country heterogeneity in elasticities of substitution, we perform the same global tariff war experiment, but we instead assume that all countries share the same utility function (i.e. the same elasticities of substitution) as in the U.S. We refer to this setting as the model with homogeneous elasticities. To perform this counterfactual, we re-calibrate

[21] As can be seen in Table 3, there are still slight differences in the tariff contributions across the two models which suggests that the change in trade volumes is slightly different between the two models. This difference is primarily due to general equilibrium effects.

both the baseline and perfect competition models to the 2015 data. Table 4 reports the results. Like in the model with heterogeneous elasticities, the difference between the average import and the average export markup has a large predictive power for the welfare results in the baseline model. This can be seen in Figure 4a: countries which disproportionately import higher-markup goods lose less (or even gain) from the global tariff war.[22] For example, for China and Vietnam, the welfare loss in the baseline model is around 1 percent smaller than the welfare loss in the perfect competition model. On the other hand, for Australia, Norway and Canada, the welfare loss in the baseline model is around one percent larger than the welfare loss in the perfect competition model.

Comparing Tables 3 and 4 highlights the importance of cross-country heterogeneity in elasticities. First, notice that since the elasticity of substitution does not play a crucial role in the perfect competition case, the results for this model are quite similar in these two tables.[23] In the baseline model however, ignoring any cross-country heterogeneity in elasticities would imply markedly different (and potentially misleading) predictions for import and export markups across the world, and would consequentially result in significantly different welfare implications.

To facilitate the comparison between the homogeneous- and heterogeneous-elasticity models easier, Figure 4b repeats the welfare results in the baseline model with homogeneous elasticities. The horizontal axis in Figure 4c measures the average import markup minus average export markup, for the case of heterogeneous versus homogeneous elasticities. The vertical axis in this figure shows percentage changes in welfare in the global tariff war, using our baseline model with heterogeneous elasticities versus the baseline model with homogeneous elasticities. As can be seen in this figure, for some countries, incorporating cross-country heterogeneity in $\sigma_n^{j(k)}$ reduces the average difference bewteen import and export markups and for this group, incorporating cross-country heterogeneity in elasticities therefore magnifies the loss from global tariff war in the baseline model. For example, the welfare loss from a global tariff war in the baseline model with heterogeneous elasticities is larger than that without heterogeneity by almost 3.4 percentage points for Belgium, 3.2 percentage points for Vietnam, or 2.2 percentage points in Canada.

On the other hand, as Figure 4c shows, incorporating cross-country heterogeneity in elasticities of substitution can also raise the gap between import and export markups and

[22] Moreover, as Appendix Figure E.1 shows, the welfare change from the global tariff war in the baseline model relative to that under perfect competition is increasing in the difference between the average import and export markup.

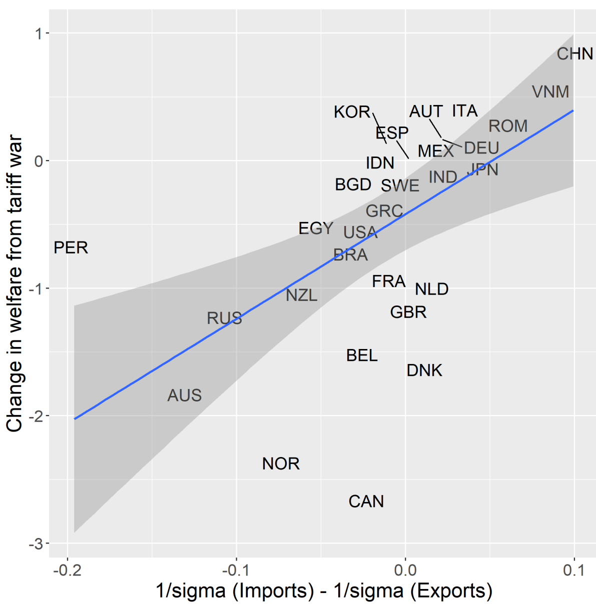
[23] Note that even in the perfect competition model the results slightly change when we add cross-country heterogeneity in elasticities. This is because in our nested-CES structure, 2-digit HS elasticities enter the equilibrium condition (24). In a model with one-tier CES structure, however, these elasticities would not have a quantitative impact at all.

Table 4: A Global Tariff War (Homogeneous Substitution Elasticities): welfare changes (%) when all countries raise all tariffs by 20 percentage points

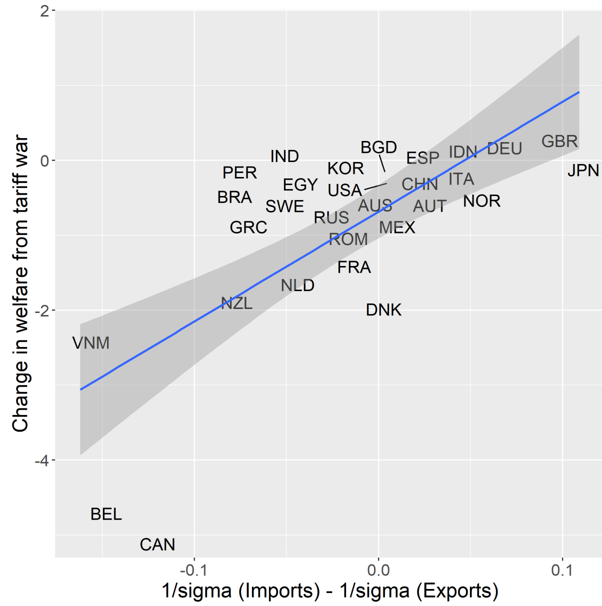
Countries	Baseline Model				Perfect Competition Model		
	welfare	wage	profit	tariff	welfare	wage	tariff
Australia	-1.748	-1.029	-1.678	0.959	-0.789	-1.755	0.966
Austria	0.184	-0.688	-0.106	0.978	-0.519	-1.492	0.972
Bangladesh	-0.097	-0.118	-0.064	0.085	-0.178	-0.263	0.085
Belgium	-1.435	-2.113	-1.708	2.385	-1.857	-4.235	2.377
Brazil	-0.647	-0.438	-0.453	0.244	-0.463	-0.708	0.245
Canada	-2.757	-2.230	-2.777	2.250	-1.672	-3.942	2.271
China	0.759	-0.210	0.706	0.262	-0.188	-0.450	0.262
Denmark	-1.555	-2.286	-1.727	2.457	-1.480	-3.939	2.459
France	-0.855	-1.030	-1.069	1.244	-0.703	-1.948	1.245
Germany	0.164	-0.658	-0.209	1.031	-0.399	-1.431	1.033
Greece	-0.328	-0.334	-0.341	0.348	-0.305	-0.654	0.349
India	-0.039	-0.082	-0.021	0.064	-0.128	-0.192	0.065
Indonesia	0.015	-0.554	-0.045	0.613	-0.521	-1.133	0.612
Italy	0.313	-0.387	0.115	0.585	-0.267	-0.851	0.584
Japan	0.012	-0.149	-0.040	0.200	-0.055	-0.256	0.200
Rep. of Korea	0.136	-0.154	0.082	0.207	-0.099	-0.307	0.207
Mexico	0.003	-1.283	-0.359	1.645	-0.616	-2.258	1.642
Netherlands	-0.917	-1.166	-1.162	1.411	-0.896	-2.310	1.413
New Zealand	-1.138	-0.913	-1.118	0.893	-0.672	-1.568	0.897
Norway	-2.286	-1.215	-2.224	1.154	-0.920	-2.086	1.166
Peru	-0.585	-0.229	-0.538	0.182	-0.165	-0.348	0.183
Romania	0.191	-0.356	0.022	0.526	-0.205	-0.729	0.524
Russia	-1.318	-0.485	-1.223	0.391	-0.433	-0.828	0.394
Vietnam	0.633	-1.126	0.636	1.123	-0.958	-2.067	1.109
Spain	0.019	-0.251	-0.131	0.402	-0.221	-0.623	0.401
Sweden	-0.109	-0.574	-0.395	0.860	-0.443	-1.302	0.860
Egypt	-0.435	-0.283	-0.363	0.211	-0.379	-0.591	0.212
United Kingdom	-1.048	-1.272	-1.018	1.241	-0.910	-2.154	1.244
USA	-0.471	-0.333	-0.532	0.394	-0.302	-0.696	0.394
ROW	-2.810	-2.085	-2.774	2.049	-1.434	-3.571	2.136

Notes: The first four columns associate with the baseline model, and the last three columns are associated with the perfect competition model. Columns "welfare" report the percentage change in welfare. Based on the welfare decomposition (30), we decompose the welfare changes into the percentage change in real wages, real profits, and real tariff revenues, reported in columns "wage", "profit", and "tariff", respectively. We assume all countries share the same elasticities of substitution as in the U.S. Numbers are rounded to the nearest thousandth.

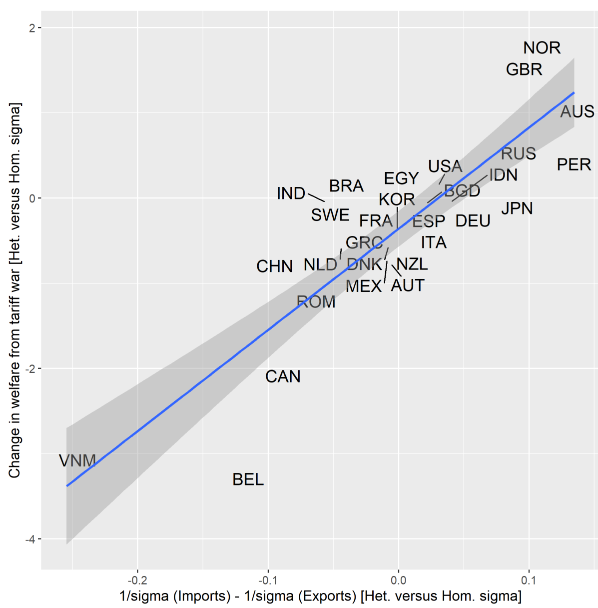
Figure 4: Welfare Consequences of Global Tariff War



(a) Baseline Model (Homogeneous Elasticities)



(b) Baseline Model (Heterogeneous Elasticities)



(c) Baseline Model (Heterogeneous versus Homogeneous Elasticities)

Notes: The horizontal axis measures average import markup minus average export markup for each country, where in (a) we assume all countries share the same elasticities of substitution as in the U.S. (homogeneous elasticities), and in (b) we allow for cross-country heterogeneous elasticities. The horizontal axis in (c) measures average import markup minus average export markup, for the case of heterogeneous versus homogeneous elasticities. The vertical axis is percentage changes in welfare from the global tariff war using our baseline model with (a) homogeneous elasticities, and (b) heterogeneous elasticities. The vertical axis in (c) is percentage changes in welfare from the global tariff war using our baseline model with heterogeneous elasticities versus the baseline model with homogeneous elasticities. The shaded areas reflect linear fitted lines along with their 95% confidence bands.

for these countries, the welfare loss from a global tariff war is attenuated in the baseline model. For instance, the welfare loss from global tariff war in the baseline model with heterogeneity is smaller than that without heterogeneity by almost 1.9 percentage points for Norway, 1.1 percentage points for Australia and the U.K., and 0.7 percentage points for Russia.

Importantly, in addition to such quantitative differences, introducing heterogeneous elasticities can even change the qualitative consequences of a global tariff war. Specifically, while Austria, China, or Indonesia lose from the trade war in the baseline model with heterogeneous elasticities, they gain in the baseline model with homogeneous elasticities. This is the exact opposite for the case of the U.K. It is worth mentioning that there are two countries that gain from this global tariff war in the baseline model with or without heterogeneous elasticities: Germany and Japan. For these two countries, as Figures 4a and 4b show, the average difference between the import and export markup is relatively high, with or without heterogeneous elasticities.

More generally, these results also highlight that a main reason for the large welfare implications of profit shifting is the presence of a significant degree of variation in country-product specific elasticities of substitution. As evident from Figures 4a and 4c, once this variation is removed, we obtain more moderate welfare effects for e.g. Belgium, Vietnam, and Canada, and welfare changes range only from -2.8% to 0.7% compared to -5.0% to 0.1% in the full model. Interestingly, in this case, we find that poorer economies such as Vietnam, Romania, and China export goods with significantly lower markups compared to their imports, which results in import tariffs generating strong gains from profit shifting for those countries. Importantly, this result is entirely driven by differences in the product mix that is imported versus that which is exported. Hence, one may interpret 4a as indicative of the welfare consequences of profit shifting due to differences in the composition of exports and imports, while the remaining variation can be explained by country-product specific differences in $\sigma_n^{j(k)}$ due to e.g. differences in demand.

Appendix Tables E.3 and E.4 show in more detail why the results differ in this case for three example countries Germany, Belgium, and China. Most noticeably, Belgium's import and export markups are now much more similar for its largest import and export sectors with the result that the welfare implications under imperfect and perfect competition are much more aligned in this case (see Table 4). For China, on the other hand, the average import markup increases slightly while the average export markup drops significantly. As a consequence, China experiences markedly stronger gains from profit shifting in the case of homogeneous elasticities.

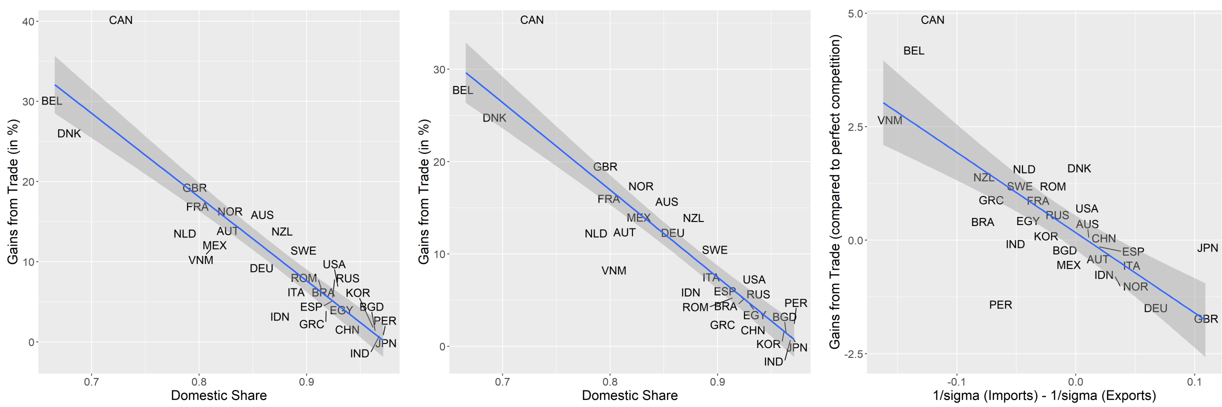
The Role of the Magnitude and Sectoral Heterogeneity in Trade Elasticities As the simple model in Section 4 suggests, the profit-shifting channel is stronger when productivities across countries are less dispersed, i.e., if the trade elasticities θ are larger. To examine this relationship quantitatively, we raise all trade elasticities by 50% and perform the same global tariff war counterfactual experiment as above. Appendix Table E.5 reports the results. Under perfect competition, welfare losses from this global trade war are close to those in Table 3 even though the trade elasticities are now 50% larger. As expected, however, the welfare results under imperfect competition are quite different from those in Table 3. In particular, the welfare loss from this global trade war for the net exporters of high-markup products (e.g., Belgium, Canada, and Vietnam) is even larger when trade elasticities are higher. This result is due to the goods that were previously exported by high-markup exporters being now more easily substituted by domestic varieties after the global war. For the same reason, the welfare gain for net importers of high-markup goods (e.g. the UK, Germany, and Japan) is larger when trade elasticities are larger.

In order to assess the importance of sectoral heterogeneity in the Frechet parameter θ, we also recomputed the impact of tariffs when θ is set equal to the median value of 3.69 in all sectors. Appendix Table E.6 reports the results. We generally find that sectoral heterogeneity in trade elasticities can affect countries in either direction and either amplify or mitigate losses from tariffs. We do however also find that the welfare results are considerably less affected than by variation in the elasticities of substitution and only contribute to additional welfare changes of between -0.4 and 0.5 percentage points. The reason for this observation is likely that there is little correlation between sectoral differences between import and export markups and the corresponding values of $\theta^{j(k)}$.[24]

Gains from Trade As an extreme case of a global tariff war, we move all tariffs to infinity to calculate the gains from trade, i.e., percentage changes in welfare as we move from the observed trade volumes in 2015 to autarky. Appendix D outlines the procedure to numerically solve for the gains from trade, and Appendix Table D.1 reports the results. As expected, the gains from trade are larger for smaller countries, as evident from the strongly negative correlation between domestic shares and the gains from trade in Figure 5a. Moreover, comparing the gains from trade in the baseline model with those in the perfect

[24] To study this relationship further, we also experimented with weighting each country's sectoral import and export inverse elasticities not just by trade volume, but also by the sectoral θ. The idea is that for a given country and a given sector for which the import markup is higher than the export markup, a higher trade elasticity would imply that this markup difference is more relevant than one in other sectors with a low trade elastisticity. We did however only find a small correlation between this adjusted markup gap and the difference between the baseline model and the homogeneous-θ setting. This suggests that sectoral heterogeneity in the trade elasticity does in practice affect the quantitative importance of profit shifting only moderately.

Figure 5: The Gains from Trade



(a) Baseline Model (b) Perfect Competition (c) Baseline vs. Perfect Comp.

Notes: The vertical axis in each plot shows the gains from trade measured in percent. The horizontal axis in Panels a) and b) reflect each country's domestic share, i.e. the fraction of expenditure that is spent on domestic goods. The horizontal axis in Panel c) measures average import markup minus average export markup by a country. The shaded areas reflect linear fitted lines along with their 95% confidence bands.

competition model (Figure 5c) reveals that profit shifting continues to be important for the gains from trade. Specifically, while for countries like Belgium, Canada, and New Zealand with large export markups relative to import markups the gains from trade are larger in the baseline model than in the perfect competition model, the opposite is true for countries like the U.K., Germany, and Japan with relatively high import markups than export markups.

Interestingly, however, we find that the gains from trade tend to be less sensitive to profit shifting than the welfare consequences of tariff wars, as evident from the fact that for many countries, the perfect and imperfect competition settings have quite similar implications for the gains from trade. This is important in so far as it suggests that a perfect competition framework, at least to a first-order approximation, appears to be well suited to predict the gains from trade even in a multi-sector setting with heterogeneous demand elasticities, while it appears to result in misleading implications of the consequences of trade wars and talks. We will show below for example, that profit shifting significantly alters the predicted implications of the 2018-19 U.S.-China trade war.

Finally, cross-country heterogeneity in the elasticity of substitution continues to play an important role in the gains from trade as well. To show this, Appendix Table D.2 computes the gains from trade for the case in which we assume all countries share the same elasticities as those estimated for the U.S. Comparing Tables D.1 and D.2 shows that by ignoring the cross-country heterogeneity in these elasticities, the gains from trade tend to be underestimated for most countries.

Unilateral Increase in the U.S. Tariffs We also examine the consequences of a unilateral increase in tariffs by the U.S., in the absence of any retaliation by U.S. trading partners. To do so, we raise all U.S. import tariffs by 20 percentage points in both our baseline model and the perfect competition variant of our model. Appendix Table E.7 reports the results. Interestingly, the U.S. gains in the baseline model are much larger than those under perfect competition (0.264 vs 0.158%). Moreover, note that this larger gains for the U.S. in the baseline model is not due to a larger tariff revenue; indeed, the change in tariff revenue is identical in these two models. Instead, what is happening is that a unilateral tariff increase in the baseline model shifts profits to the U.S. economy, which mitigates the losses from higher prices.

Competing at 2-digit HS level In the model developed in Section 3, we employed a nested-CES structure in which firms compete in 6-digit HS categories, and therefore, face 6-digit HS demand elasticities. Here, we explore how our counterfactual results change with the level of aggregation at which firms are competing. To do so, we slightly change the structure of the model by employing a one-tier CES structure in which firms compete in 2-digit, rather than 6-digit, HS categories. This modified model ("HS2 model," hereafter) along with the equilibrium conditions is outlined in Appendix C. To perform the counterfactual experiments in this modified model, we use the same trade elasticities as before.[25] Appendix Table E.8 reports the results for the global tariff war studied above and shows that overall, we find that there are now several countries that gain in this scenario. The intuition for this result is that the dispersion in trade shares at the HS6 level is generally higher than that at HS2 level. Hence, when we use the aggregated data at the HS2 level, the differences in inferred productivities are less pronounced, and therefore, the losses from higher tariffs become smaller. Hence, the profit shifting channel makes more countries better off in this global war.

6.2 Welfare Consequences of the U.S.-China Tariff War

This section studies the welfare consequences of the 2018-19 U.S.-China tariff war. We perform two counterfactual experiments: In the first exercise, we use the factual tariffs imposed by the U.S. on imports from China in 2018, and the retaliatory tariffs imposed by China on goods imported from the U.S. In the second experiment, we change the set of goods for which U.S. and China impose tariffs against each other, and explore how the welfare results differ.

[25] Recall that our trade elasticities vary only across the 2-digit HS codes.

6.2.1 The Factual U.S.-China Tariff War

In March 2018, the U.S. government initiated a series of trade policy measures with the announcement of tariffs on steel and aluminum of 25% and 10%, respectively. A month later, U.S. President Trump released a list of more than 1,300 goods under consideration for a 25% tariff on China based on the argument that China dealt "Harm to American intellectual property rights, innovation or technology". This announcement was the starting point for several waves of bilateral tariffs by both the U.S. and China: According to Fajgelbaum et al. (2020), by the end of 2018 more that \$300 billion (about 12 percent) of U.S. were subject to tariffs and the average tariff rate imposed by both countries on each other rose to levels above 20% in 2019.

In this section, we use both our baseline and the perfect competition model to study the welfare consequences of this factual U.S.-China tariff war. Table 5 reports the results. In the perfect competition model, both the U.S. and China lose from this U.S.-China tariff war by 0.04 and 0.047 percent, respectively. As expected, this finding is due to the tariff war reducing real wage in both economies because of an increase in the price index under perfect competition. Tariff revenues in both countries rise, but not enough to compensate the decline in real wage. Notice that the decline in welfare of 0.04 for the U.S. exactly matches the findings by Fajgelbaum et al. (2020), that were obtained under the assumption of perfect competition, which is reassuring and suggests that our results in the perfect competition case are not based on unusual assumptions or parameter estimates.

Our welfare results do however change significantly when we allow for imperfect competition and profit-shifting: While the U.S. loses from this tariff war by 0.092 percent, China gains by 0.02 percent. To explore this result, notice that real wage in both economies fall, due to the increase in the price index. Real profit, however, rises in China while it falls in the U.S. The fall in real profit in the U.S. magnifies the welfare loss for the U.S. relative to the perfect competition model (-0.092 percent in baseline versus -0.04 percent in perfect competition). The rise in real profit in China, on the other hand, compensates the decline in real wage, which in turn make China better off from this tariff war. Hence our baseline model, compared to the perfect competition model, changes both the quantitative and, more importantly, qualitative consequences of the U.S.-China tariff war.

To see why real profit falls in the U.S. while it rises in China, note that the average inverse elasticity of the goods on which the U.S. places tariffs (weighted by trade volume and the tariff rate) is 0.24 compared to 0.36 for China. Hence, even though the imposed tariffs were fairly uniformly distributed across sectors, the average markup of the industries on which the U.S. imposed tariffs was considerably smaller than that for China, due to differences in the product mix of China's exports versus that of its imports. Effectively, the U.S. therefore imposed import tariffs on low markup goods significantly more than China, and China taxed high markup goods relatively more. As a result, the U.S.-China tariff war disproportionately shifted profits from the U.S. to China, leading to a decline in real profits in the U.S. and a rise in real profits in China. In addition, while workers in both countries and also firm owners in the U.S. experienced losses in this tariff war, firm owners in China gained.

Appendix Table E.10 provides more details on why exactly this is the case and summarizes the average inverse elasticities for imports and exports in the 20 largest 2-digit sectors as well as the tariffs that were imposed by the U.S. and China. As evident from the table, products imported by China are on average significantly higher-markup goods than those which it exports for the 4 largest broadly defined sectors in the dataset (machinery, furniture, and synthetic categories). This means that for about 70% of the observed trade volume, China imposes tariffs on higher-markup goods, while the U.S. taxes lower-markup imports, which translates into profits shifting from the U.S. to China. Notice that the average tariff is actually fairly comparable across sectors, so the main reason for this finding is simply that the U.S. exports higher-markup goods to China than vice versa for the majority of sectors. This suggests that this result is less due to the specific tariffs that were chosen by the U.S. in this case, but more due to general differences in the type of goods offered by both countries.

Finally, among third-party countries, the U.S.-China tariff war has a particularly strong impact on countries close to the U.S. and China, such as Canada, Mexico, and Vietnam. However, also welfare predictions for these countries are affected by profit shifting: While almost all countries benefit from the U.S.-China trade war due to trade diversion, these gains tend to be smaller under imperfect competition. The reason is that, compared to other countries, the imports of both the U.S. and China tend to be higher-markup goods than their exports. Therefore, when shifting to trade with other countries, the U.S. and China experience moderate gains from profit shifting at the expense of these third-party countries.

A Uniform U.S.-China Tariff War So far we examined the welfare consequences of the observed U.S.-China tariff war in which U.S. and China impose additional tariffs on some targeted industries. In this observed tariff war, some industries are hence targeted more than others. To see how the welfare results would look like if U.S. and China raise all tariffs uniformly across industries, we do the following counterfactual analysis: U.S. and China raise tariffs across all 6-digit sectors by 20 percentage points. Table E.11 in Appendix E reports the results.

We find that in this case, both the welfare losses experienced by the U.S. (-0.13% versus

Table 5: The Factual U.S.-China Tariff War: welfare changes (%) given the observed U.S.-China tariff war

Countries	Baseline Model				Perfect Competition Model		
	welfare	wage	profit	tariff	welfare	wage	tariff
Australia	-0.005	-0.002	-0.004	0.000	-0.003	-0.003	0.000
Austria	-0.001	0.001	-0.002	0.000	0.002	0.001	0.000
Bangladesh	0.001	0.001	0.000	0.000	0.001	0.001	0.000
Belgium	-0.002	0.000	-0.002	-0.000	0.000	0.000	-0.000
Brazil	-0.001	0.000	-0.002	0.000	0.001	0.001	0.000
Canada	0.007	0.006	0.001	0.001	0.010	0.009	0.001
China	0.020	-0.041	0.044	0.017	-0.047	-0.064	0.017
Denmark	0.003	0.002	-0.000	0.001	0.005	0.004	0.001
France	0.002	0.002	0.000	0.000	0.003	0.002	0.000
Germany	-0.000	0.002	-0.002	0.000	0.003	0.003	0.000
Greece	0.001	0.000	0.000	0.000	0.000	0.000	0.000
India	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Indonesia	-0.000	0.001	-0.001	-0.000	0.002	0.002	-0.000
Italy	-0.001	0.001	-0.002	0.000	0.001	0.001	0.000
Japan	-0.000	0.001	-0.001	0.000	0.001	0.001	0.000
Rep. of Korea	0.000	0.000	-0.000	0.000	0.001	0.001	0.000
Mexico	0.006	0.014	-0.010	0.001	0.022	0.021	0.001
Netherlands	0.001	0.001	-0.000	0.000	0.002	0.002	0.000
New Zealand	-0.014	-0.001	-0.013	-0.000	-0.002	-0.002	-0.000
Norway	0.003	0.001	0.001	0.000	0.002	0.002	0.000
Peru	0.002	-0.000	0.002	0.000	-0.000	-0.000	0.000
Romania	-0.000	0.000	-0.001	0.000	0.001	0.000	0.000
Russia	0.001	0.000	0.001	-0.000	0.000	0.000	-0.000
Vietnam	0.004	0.007	-0.004	0.001	0.010	0.009	0.001
Spain	0.001	0.000	0.000	0.000	0.001	0.000	0.000
Sweden	0.000	0.001	-0.001	0.000	0.002	0.001	0.000
Egypt	0.001	0.000	0.001	0.000	0.001	0.000	0.000
United Kingdom	-0.000	0.001	-0.002	0.000	0.003	0.002	0.000
USA	-0.092	-0.050	-0.107	0.065	-0.040	-0.105	0.065
ROW	0.005	0.003	0.002	0.000	0.004	0.004	0.000

Notes: The first four columns associate with the baseline model, and the last three columns are associated with the perfect competition model. Columns "welfare" report the percentage change in welfare. Based on the welfare decomposition (30), we decompose the welfare changes into the percentage change in real wages, real profits, and real tariff revenues, reported in columns "wage", "profit", and "tariff", respectively. Numbers are rounded to the nearest thousandth.

-0.09%) and the gains experienced by China (0.03% versus 0.02%) are even larger than in the baseline case. This result is due to elasticity of the goods on which the U.S. and China place tariffs (weighted by trade volume and the tariff rate) is 0.25 for the U.S. and 0.39 for China compared to 0.24 and 0.36 before. The results are however still largely in line with those seen in the baseline case, which could be expected given our previous finding that import and export markups differ mainly because of general differences in the type of goods offered by both countries. Hence, profit shifting favors China even in the case of a uniform tariff.

The Role of Heterogeneous Elasticities of Substitution To explore the role of heterogeneous elasticities of substitution, we perform the same U.S.-China tariff war experiment, but we assume all countries share the same elasticities as in the U.S. Table E.12 reports the results. As discussed before, elasticities of substitution do not play almost any role in the perfect competition model, and therefore, the welfare results in this model do not change when we abstract away from heterogeneous elasticities. The welfare results in the baseline model, however, change significantly: U.S. welfare, which used to fall by 0.09 percent in the heterogeneous model, now falls by 0.17 percent, and China, which used to gain by 0.02 percent in the heterogeneous model, now gains by 0.096 percent.

To see why by imposing homogeneous elasticities welfare consequences of U.S.-China tariff war crucially change, let's look at the welfare change decomposition into the contributions of wage, profit, and tariff revenue. Comparing the results for the baseline model in Tables 5 and E.12 shows that imposing homogeneous elasticities almost does not influence the contributions of wage and tariff revenue. Note that since trade elasticities in the model with homogeneous elasticities are the same as those in the model with heterogeneous elasticities, the change in trade volumes and therefore the change in tariff revenues are almost the same in these two models.

Imposing homogeneous elasticities, however, substantially influences the change in profits, which in turn, affects the welfare consequences of this tariff war. As Tables 5 and E.12 show for the baseline model, U.S. profit loss from the U.S.-China tariff war is much larger in the case of homogeneous elasticities. On the other hand, profit gain for China magnifies in the model with homogeneous elasticities. To make sense of these results, notice that the U.S. on average has lower elasticities than China, and therefore, imposing homogeneous elasticities raises the average import markups for China. Indeed, while with heterogeneous elasticities the average inverse elasticity of the goods on which China places tariffs is 0.36, this goes up to 0.43 when using homogeneous elasticities. Hence, the model with homogeneous elasticities would imply a larger welfare gain for China and a larger welfare loss for the U.S., compared with the model with heterogeneous elasticities.

As mentioned before, the U.S.-China tariff war has consequences for many countries across the world, especially the U.S. neighbors. While, as shown in Table 5, Canada and Mexico gain from this tariff war in the baseline model with heterogeneous elasticities, they both lose in the baseline model with homogeneous elasticities (look at Table E.12). To see why, notice that the U.S. on average has lower elasticities than Canada and Mexico. Hence, imposing homogeneous elasticities raises average import markups for both Canada and Mexico, which turns their welfare gain (from more trade with the U.S.) to a welfare loss. Notice that, however, Canada and Mexico both gain from this tariff war in the perfect competition model, regardless of what we assume about elasticities of substitution. Similarly, China's inverse elasticity equals 0.42 for imports and 0.32 for exports in the homogeneous-elasticity case, which constitutes one of the largest markup gaps among countries in our sample. Therefore, China generally experiences strong gains from profit shifting which translates into welfare losses for third-party countries that now trade more with China.

6.2.2 A Counterfactual U.S.-China Tariff War

As discussed in the previous section, in the observed U.S.-China tariff war the U.S. imposes tariffs on its low-markup sectors while China imposes tariffs on its high-markup sectors. As discussed, in our baseline model, while China gains, this tariff war leads to a welfare loss for the U.S. In this section, we explore how the welfare results would look like in a counterfactual tariff war in which this markup pattern is flipped, i.e., the U.S. targets high-markup industries while China targets low-markup industries. To perform such a counterfactual, we first rank industries according to their inverse elasticities and assume that the U.S. (China), instead of using comparably homogeneous tariffs across sectors, taxes only its highest- (lowest-) markup sectors with a higher tariff of 50%. We assume that the tariff burden on both China and the U.S. are unchanged, i.e., the generated tariff revenue (before considering the change in trade volumes) for both China and the U.S. are the same as in the factual tariff war.

By construction, the average markup of the sectors targeted by the U.S. in this counterfactual tariff war is hence larger than the average markup of the sectors targeted by China. Specifically, the average inverse elasticities (weighted by trade volume and tariff rates in 2015) for the U.S. and China are 0.51 and 0.09, respectively. For example, in the factual tariff war, the U.S. placed high tariffs of 24% on the low-markup industry *Rubber* but only a 15% tariff on the high-markup sector *Clothing Accessories*. In the counterfactual tariff war, the tariff on rubber averages only about 14% while the tariff on high-markup goods is considerably higher.

Table 6 reports the counterfactual results. As the results show, in our baseline model the welfare results for the U.S. and China flip: while the U.S. gains, China loses from this counterfactual tariff war. Comparing the results of our baseline model in Tables 5 and 6 reveals that profit shifting is responsible for this result: while in the factual U.S.-China tariff war the U.S. loses profit and China gains profit, this would be the exact opposite in the counterfactual U.S.-China tariff war.

This result shows that, in our baseline model, the welfare consequences of a tariff war crucially depend on markups of the industries that a country targets, and also on the markups of those industries in which the other country retaliates. Note that, however, as is also the case in the factual U.S.-China tariff war, both the U.S. and China lose from this counterfactual tariff war in the perfect competition model.

Interestingly, this counterfactual tariff war also affects third-party countries quite differently than the factual one. Intuitively, these countries can now (1) more easily export high-markup goods to and import low-markup goods from the U.S. and (2) more easily export low-markup goods to and import high-markup goods from China. The overall impact of profit shifting therefore depends on which channel dominates and the results e.g. suggest that the change in trade with the U.S. has an overall stronger effect on welfare in Mexico than the change in trade with China, due to the country's proximity to the former. For India, however, the result is reversed, as the country is geographically closer to China.

U.S. imposes tariffs on high-markup goods, China imposes factual tariffs A natural question is whether or not the U.S. could have benefited from the trade war on aggregate, conditional on factual retaliation by China, i.e., is profit shifting potentially strong enough such that the U.S. could have actually experienced welfare gains through imposing tariffs on high-markup products? To answer this question, we recompute our results for the case in which China imposes factual trade war tariffs while the U.S. uses the counterfactual one described in the previous paragraph. As evident from Appendix Table E.13, we find that this policy would not have resulted in welfare gains for the U.S. but would essentially reduce the losses by a factor of 4. China, on the other hand, experiences losses of 0.07 percent in this case instead of welfare gains as predicted in the factual war. Such a policy could hence be in principle successful in terms of putting political pressure on China, as intended by the U.S., while reducing the cost in terms of the U.S. welfare.

Table 6: A Counterfactual U.S.-China Tariff War: welfare changes (%) when the U.S. and China impose tariffs on high-markup and low-markup sectors, respectively.

Countries	Baseline Model				Perfect Competition Model		
	welfare	wage	profit	tariff	welfare	wage	tariff
Australia	-0.003	-0.000	-0.003	0.000	-0.000	-0.000	0.000
Austria	-0.000	0.000	-0.001	0.000	0.001	0.001	0.000
Bangladesh	0.001	0.000	0.000	0.000	0.001	0.000	0.000
Belgium	-0.001	0.001	-0.003	0.000	0.002	0.002	0.000
Brazil	-0.001	0.000	-0.001	0.000	0.000	0.000	0.000
Canada	0.007	0.007	-0.000	0.000	0.009	0.009	0.000
China	-0.104	-0.025	-0.085	0.006	-0.033	-0.040	0.006
Denmark	0.001	0.001	-0.001	0.000	0.002	0.002	0.000
France	-0.001	0.001	-0.002	0.000	0.002	0.002	0.000
Germany	-0.001	0.001	-0.002	0.000	0.002	0.002	0.000
Greece	-0.000	0.000	-0.000	0.000	0.000	0.000	0.000
India	0.000	0.000	-0.000	0.000	0.000	0.000	0.000
Indonesia	-0.000	0.001	-0.001	0.000	0.001	0.001	0.000
Italy	-0.001	0.000	-0.001	0.000	0.001	0.001	0.000
Japan	-0.000	0.001	-0.001	0.000	0.001	0.001	0.000
Rep. of Korea	-0.000	0.000	-0.001	0.000	0.000	0.000	0.000
Mexico	0.017	0.006	0.011	0.000	0.008	0.008	0.000
Netherlands	0.000	0.001	-0.001	0.000	0.001	0.001	0.000
New Zealand	-0.006	-0.000	-0.006	-0.000	-0.000	-0.000	-0.000
Norway	-0.001	0.001	-0.001	0.000	0.001	0.001	0.000
Peru	0.001	0.000	0.001	0.000	0.000	0.000	0.000
Romania	-0.000	0.000	-0.000	0.000	0.000	0.000	0.000
Russia	-0.000	0.000	-0.000	-0.000	0.000	0.000	-0.000
Vietnam	0.003	0.002	0.001	0.000	0.003	0.003	0.000
Spain	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sweden	-0.000	0.000	-0.001	0.000	0.001	0.001	0.000
Egypt	0.000	0.000	-0.000	0.000	0.000	0.000	0.000
United Kingdom	-0.001	0.001	-0.002	0.000	0.002	0.002	0.000
USA	0.067	-0.035	0.079	0.022	-0.050	-0.072	0.022
ROW	-0.003	0.002	-0.005	-0.000	0.003	0.003	0.000

Notes: The first four columns associate with the baseline model, and the last three columns are associated with the perfect competition model. Columns "welfare" report the percentage change in welfare. Based on the welfare decomposition (30), we decompose the welfare changes into the percentage change in real wages, real profits, and real tariff revenues, reported in columns "wage", "profit", and "tariff", respectively. Numbers are rounded to the nearest thousandth.

7 Conclusion

In this paper, we developed a multi-sector, multi-country model of international trade with imperfect product markets which embeds markups into Eaton and Kortum (2002)'s Ricardian trade model. We used our framework to highlight the importance of profit shifting in a setting with country- and industry-specific markups and industry-specific firm heterogeneity. Our results suggest that profit shifting can have meaningful qualitative and quantitative implications for both the gains from trade and especially the welfare consequences of trade wars. Further, our findings imply that the way in which tariff policy is implemented can have widely different implications for welfare of both the imposing and the retaliating country.

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Appendices

A Price Indices and Expenditure Shares

The productivity of country i in producing a variety ω in sector $j(k)$ is the realization of a random variable $z_i^{j(k)}$. This random variable is drawn from a Fréchet distribution $F_i^{j(k)}(z) = e^{T_i^{j(k)} z^{-\theta^{j(k)}}}$. The marginal cost of exporting this variety from country i to country n by a firm with productivity $z_i^{j(k)}$, denoted by $c_{in}^{j(k)}(z_i^{j(k)})$ is the realization of the random variable $c_{in}^{j(k)}(z_i^{j(k)}) = w_i \tau_{in}^{j(k)} / z_i^{j(k)}$. Note that the marginal cost also follows the Fréchet distribution:

$$Pr[c_{in}^{j(k)}(\omega) < c] = 1 - e^{-\lambda_{in}^{j(k)} c^{\theta^{j(k)}}} \tag{59}$$

where, $\lambda_{in}^{j(k)} = T_i^{j(k)}(w_i \tau_{in}^{j(k)})^{-\theta^{j(k)}}$. Given this and using equation (11), the lowest price of a variety in country n will also have a Fréchet distribution:

$$Pr[p_n^{j(k)} < p] = 1 - \Pi_{i=1}^{N} Pr\big(c_{in}^{j(k)} \geq \frac{\sigma_n^{j(k)} - 1}{\sigma_n^{j(k)}} p\big) \tag{60}$$

and using equation (59) we obtain

$$Pr[p_n^{j(k)} < p] = \Big(1 - e^{-\Phi_n^{j(k)} p^{\theta^{j(k)}}}\Big) \tag{61}$$

where $\Phi_n^{j(k)} = (\frac{\sigma_n^{j(k)}-1}{\sigma_n^{j(k)}})^{\theta^{j(k)}} \sum_{i=1}^{N} T_i^{j(k)} (w_i \tau_{in}^{j(k)})^{-\theta^{j(k)}}$ describes the state of technologies, wages and trade costs across the world.

Using equations (8) and (61), the price index is given as

$$P_n^{j(k)^{1-\sigma_n^{j(k)}}} = \int p^{1-\sigma_n^{j(k)}} p^{\theta^{j(k)}-1} \theta^{j(k)} \Phi_n^{j(k)} e^{-\Phi_n^{j(k)} p^{\theta^{j(k)}}} dp \tag{62}$$

Let $x = \Phi_n^{j(k)} p^{\theta^{j(k)}}$. Then, we can write the price index as

$$P_n^{j(k)^{1-\sigma_n^{j(k)}}} = \int \Phi_n^{j(k)^{\frac{\sigma_n^{j(k)}-1}{\theta^{j(k)}}}} x^{\frac{1-\sigma_n^{j(k)}}{\theta^{j(k)}}} e^{-x} dx \tag{63}$$

We can compute the above integral using the Gamma function, which yields:

$$P_n^{j(k)} = A_n^{j(k)} [\sum_{i=1}^{N} T_i^{j(k)} (w_i \tau_{in}^{j(k)})^{-\theta^{j(k)}}]^{\frac{-1}{\theta^{j(k)}}} \tag{64}$$

where $A_n^{j(k)} = (\frac{\sigma_n^{j(k)}}{\sigma_n^{j(k)}-1})\Gamma\left(\frac{1-\sigma_n^{j(k)}+\theta^{j(k)}}{\theta^{j(k)}}\right)^{\frac{1}{1-\sigma_n^{j(k)}}}$

To derive the expenditure shares $\pi_{in}^{j(k)} = X_{in}^{j(k)}/X_n^{j(k)}$, note that

$$X_{in}^{j(k)} = Pr\left[c_{in}^{j(k)} \leq \min_{h\neq i} c_{hn}^{j(k)}\right] X_n^{j(k)} \tag{65}$$

where $c_{in}^{j(k)} = w_i \tau_{in}^{j(k)}/z_i^{j(k)}$. Using equation (59), we derive equation (13) in the paper:

$$X_{in}^{j(k)} = \frac{T_i^{j(k)}(w_i \tau_{in}^{j(k)})^{-\theta^{j(k)}}}{\sum_{h=1}^{N} T_h^{j(k)}(w_h \tau_{hn}^{j(k)})^{-\theta^{j(k)}}} X_n^{j(k)}$$

B Solving for Equilibrium

As explained in the body of the article, we solve the model in relative changes following the steps below:

i) We first make a guess on $\hat{w}_n$.

ii) Compute $\hat{P}_n^{j(k)}$ using equation (20).

iii) Use equation (21) to compute $\hat{\pi}_{in}^{j(k)}$.

iv) Use the system of equations (24)-(27) to solve for counterfactual expenditures $X_n^{\prime j(k)}$.

v) Check the trade balance equation (28). If it is satisfied, we are done. Otherwise, we update our guess on $\hat{w}_n$ and go back to step (ii).

Step (iv) merits further explanation. To solve for the counterfactual expenditures $X_n^{\prime j(k)}$, we use the equations (25)-(27) into (24) to write:

$$\begin{aligned} X_n^{\prime j(k)} = \frac{\alpha_n^k X_n^{j(k)} \hat{P}_n^{j(k)\ 1-\sigma_n^k}}{\sum_{l=1}^{J(k)} \hat{P}_n^{l(k)\ 1-\sigma_n^k} X_n^{l(k)}} \big[\hat{w}_n w_n L_n + \sum_{k=1}^{K}\sum_{j=1}^{J(k)}\sum_{i=1}^{N} \frac{\pi_{ni}^{\prime j(k)} X_i^{\prime j(k)}}{\sigma_i^{j(k)}(1+t_{ni}^{\prime j(k)})} + \\ \sum_{k=1}^{K}\sum_{j=1}^{J(k)}\sum_{i=1}^{N} \frac{t_{in}^{\prime j(k)}}{(1+t_{in}^{\prime j(k)})} \pi_{in}^{\prime j(k)} X_n^{\prime j(k)} + D_n\big] \end{aligned} \tag{66}$$

This is a system of $J \times K \times N$ equations and unknowns to be solved for counterfactual expenditures in each sub-sector j of sector k in country n. Let's re-write this system of equations in matrix form:

$$\Lambda X = \Psi \tag{67}$$

where

$$X = \begin{pmatrix} X_1^{\prime 1(1)} \\ \vdots \\ X_1^{\prime J(1)} \\ \vdots \\ X_1^{\prime J(K)} \\ \vdots \\ X_N^{\prime 1(1)} \\ \vdots \\ X_N^{\prime J(K)} \end{pmatrix}_{JKN\times 1} \quad ; \quad \Psi = \begin{pmatrix} \xi_1^{1(1)}(\hat{w}_1 w_1 L_1 + D_1) \\ \vdots \\ \xi_1^{J(1)}(\hat{w}_1 w_1 L_1 + D_1) \\ \vdots \\ \xi_1^{J(K)}(\hat{w}_1 w_1 L_1 + D_1) \\ \vdots \\ \xi_N^{1(1)}(\hat{w}_N w_N L_N + D_N) \\ \vdots \\ \xi_N^{J(K)}(\hat{w}_N w_N L_N + D_N) \end{pmatrix}_{JKN\times 1}$$

and

$$\xi_n^{j(k)} = \frac{\alpha_n^k X_n^{j(k)} \hat{P}_n^{j(k)\ 1-\sigma_n^k}}{\sum_{l=1}^{J(k)} \hat{P}_n^{l(k)\ 1-\sigma_n^k} X_n^{l(k)}}$$

The matrix Λ is a square matrix with size $J \times K \times N$ defined as:

$$\Lambda = \mathcal{I} - \mathcal{T} - \Pi$$

where $\mathcal{I}$ is the identity matrix, and

$$\mathcal{T} = \begin{pmatrix} \Xi_1 \otimes T_1 & 0_{JK\times JK} & \dots & 0_{JK\times JK} \\ 0_{JK\times JK} & \Xi_2 \otimes T_2 & \dots & 0_{JK\times JK} \\ \vdots & \vdots & \ddots & \vdots \\ 0_{JK\times JK} & 0_{JK\times JK} & \dots & \Xi_N \otimes T_N \end{pmatrix}_{JKN\times JKN}$$

$$\Xi_n = \begin{pmatrix} \xi_1^{1(1)} \\ \vdots \\ \xi_1^{J(1)} \\ \vdots \\ \xi_1^{J(K)} \end{pmatrix}_{JK\times 1} \quad ; \quad T_n = \begin{pmatrix} \tilde{T}_n^{1(1)} & \dots & \tilde{T}_n^{J(1)} & \dots & \tilde{T}_n^{J(K)} \end{pmatrix}_{1\times JK} ; \quad \tilde{T}_n^{j(k)} = \sum_{i=1}^{N} \frac{t_{in}^{\prime j(k)}}{(1 + t_{in}^{\prime j(k)})} \pi_{in}^{\prime j(k)}$$

$$\Pi = \begin{pmatrix} \xi_1^{1(1)}\tilde{\pi}_{11}^{1(1)} & \dots & \xi_1^{1(1)}\tilde{\pi}_{11}^{J(1)} & \dots & \xi_1^{1(1)}\tilde{\pi}_{11}^{J(K)} & \dots & \xi_1^{1(1)}\tilde{\pi}_{1N}^{1(1)} & \dots & \xi_1^{1(1)}\tilde{\pi}_{1N}^{J(K)} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \xi_1^{J(1)}\tilde{\pi}_{11}^{1(1)} & \dots & \xi_1^{J(1)}\tilde{\pi}_{11}^{J(1)} & \dots & \xi_1^{J(1)}\tilde{\pi}_{11}^{J(K)} & \dots & \xi_1^{J(1)}\tilde{\pi}_{1N}^{1(1)} & \dots & \xi_1^{J(1)}\tilde{\pi}_{1N}^{J(K)} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \xi_1^{J(K)}\tilde{\pi}_{11}^{1(1)} & \dots & \xi_1^{J(K)}\tilde{\pi}_{11}^{J(1)} & \dots & \xi_1^{J(K)}\tilde{\pi}_{11}^{J(K)} & \dots & \xi_1^{J(K)}\tilde{\pi}_{1N}^{1(1)} & \dots & \xi_1^{J(K)}\tilde{\pi}_{1N}^{J(K)} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \xi_N^{1(1)}\tilde{\pi}_{N1}^{1(1)} & \dots & \xi_N^{1(1)}\tilde{\pi}_{N1}^{J(1)} & \dots & \xi_N^{1(1)}\tilde{\pi}_{N1}^{J(K)} & \dots & \xi_N^{1(1)}\tilde{\pi}_{NN}^{1(1)} & \dots & \xi_N^{1(1)}\tilde{\pi}_{NN}^{J(K)} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \xi_N^{J(K)}\tilde{\pi}_{N1}^{1(1)} & \dots & \xi_N^{J(K)}\tilde{\pi}_{N1}^{J(1)} & \dots & \xi_N^{J(K)}\tilde{\pi}_{N1}^{J(K)} & \dots & \xi_N^{J(K)}\tilde{\pi}_{NN}^{1(1)} & \dots & \xi_N^{J(K)}\tilde{\pi}_{NN}^{J(K)} \end{pmatrix}_{JKN \times JKN}$$

$$\tilde{\pi}_{ni}^{j(k)} = \frac{\pi_{ni}^{\prime j(k)}}{\sigma_i^{j(k)}(1 + t_{ni}^{\prime j(k)})}$$

We solve for the vector of counterfactual expenditures X by inverting the matrix Λ:

$$X = \Lambda^{-1}\Psi$$

C The Alternative Model: Competing at HS2 Level

The model we develop here is similar to the baseline model presented in Section 3, with one difference: here, there is no nested CES structure. Hence, all varieties compete at the 2-digit HS, rather than 6-digit HS, level.

C.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.

C.2 Preferences and Demand Schedules

Preferences of the representative agent in country n are given by the following Cobb-Douglas function over all sectors:

$$U_n = \Pi_{k=1}^{K} Q_n^{k\ \alpha_n^k}\ , \qquad \sum_{k=1}^{K} \alpha_n^k = 1 \quad \forall n \in \{1, ..., N\} \tag{68}$$

where Q_n^k and α_n^k are sector k composite good and its expenditure share in country n, respectively. The composite good Q_n^k is a CES aggregate over a continuum of varieties ω, each sourced from the lowest-cost supplier across the world:

$$Q_n^k = [\int r_n^k(\omega)^{\frac{\sigma_n^k - 1}{\sigma_n^k}} d\omega]^{\frac{\sigma_n^k}{\sigma_n^k - 1}} \tag{69}$$

where $r_n^k(\omega)$ is the demand for variety ω in sector k in country n, and parameter σ_n^k measures elasticity of substitution between varieties in sector k in country n. These elasticities are allowed to differ across sub-sectors and countries. We assume that the share of each variety is infinitesimal. equation (69) implies the following demand function for variety ω of sector k in country n:

$$r_n^k(\omega) = (\frac{p_n^k(\omega)}{\mathcal{P}_n^k})^{-\sigma_n^k} Q_n^k \tag{70}$$

where $p_n^k(\omega)$ is the price charged in country n by the lowest-cost producer of variety ω in sector k across the world. The CES price index $\mathcal{P}_n^k$ is defined as

$$\mathcal{P}_n^k = [\int p_n^k(\omega)^{1-\sigma_n^k} d\omega]^{\frac{1}{1-\sigma_n^k}} \tag{71}$$

Moreover, given the Cobb-Douglas preferences (68), consumers in country n face the following price index:

$$\mathcal{P}_n = \Pi_{k=1}^{K} (\frac{\mathcal{P}_n^k}{\alpha_n^k})^{\alpha_n^k} \tag{72}$$

C.3 Trade Frictions

Selling a variety of sector k from country i to country n is subject to an Ad Valorem tariff t_{in}^k and an iceberg cost d_{in}^k. The existence of the iceberg cost means that to deliver one unit of a variety in sector k from country i to country n, country i needs to ship d_{in}^k units of this good, since a fraction of this good melts on the way. For future references define trade friction as

$$\tau_{in}^k = d_{in}^k (1 + t_{in}^k) \tag{73}$$

We assume the trade friction satisfies the triangle inequality: $\tau_{ih}^k \tau_{hn}^k \geq \tau_{in}^k$.

C.4 Technology and Product Market Structure

Variety ω in sector k in country n is produced using a Constant Returns to Scale technology using labor only:

$$q_n^k(\omega) = z_n^k(\omega) l_n^k(\omega) \tag{74}$$

where $z_n^k(\omega)$ is the productivity of this producer, and we assume technology of production is proprietary. We follow the probabilistic formulation in Eaton and Kortum (2002) and Caliendo and Parro (2015) and assume productivities in sector k in country n are drawn from a Fréchet distribution with location parameter T_n^k and shape parameter θ^k. We assume productivity draws are independent across firms, sectors, and countries.

Variety ω in sector k in country n is sourced from the lowest-cost producer across the world. Each producer needs to pay the production cost upfront before producing the good. To finance the production cost, producers across the world borrow from a frictionless perfectly competitive international financial market with zero net interest rate.[26] Since the production cost has to be paid upfront, the producer that can deliver the variety ω in sector k to country n with the lowest cost charges the optimal Dixit-Stiglitz markup $\frac{\sigma_n^k}{\sigma_n^k - 1}$ over its marginal cost. Note that even though the price that the lowest-cost producer charges may be larger than some other producers' marginal costs, the other producers do not have an incentive to pay production cost and enter this market, because there is a threat to these other producers if they enter: these producers know that if they enter, the lowest-cost producer would charge a price below their marginal costs to take over the market, and in this case, those other producers would earn negative profit because they have already paid the production cost. In this pricing game, the unique equilibrium is the one in which the lowest-cost producer charges the optimal Dixit-Stiglitz markup $\frac{\sigma_n^k}{\sigma_n^k - 1}$, and the other producers stay out of the market.[27] Hence, the price for variety ω in sector k in country n is

$$p_n^k(\omega) = (\frac{\sigma_n^k}{\sigma_n^k - 1}) \times \min_i \{ \frac{w_i \tau_{in}^k}{z_i^k(\omega)} \} \tag{75}$$

where w_i is the wage in country i.

[26] We assume international financial markets are frictionless and perfectly competitive, so the equilibrium net interest rate would be zero.

[27] Rather than assuming that production cost has to be paid upfront, we can use the following assumption which delivers the same equilibrium prices: firms have to pay a tiny fixed operation cost. Since the fixed cost is tiny, we do not include it in our equilibrium conditions below.

C.5 Trade Shares and Total Income

Similar to what we showed in Appendix A, we can use the price equation (75) along with the properties of Fréchet distribution to derive the price index $\mathcal{P}_n^k$ in (71):

$$\mathcal{P}_n^k = A_n^k [\sum_{i=1}^{N} T_i^k (w_i \tau_{in}^k)^{-\theta^k}]^{\frac{-1}{\theta^k}} \tag{76}$$

where A_n^k is a constant including the Dixit-Stiglitz markup $\frac{\sigma_n^k}{\sigma_n^k - 1}$. Let X_n^k be total expenditure on sector k in country n, and let X_{in}^k be the expenditure in country n made on sector k goods sourced from country i. Then, using the Fréchet distribution properties and similar to what we did in Appendix A, we can derive the share of country i in country n's expenditure on sector k as

$$\frac{X_{in}^k}{X_n^k} \equiv \pi_{in}^k = \frac{T_i^k (w_i \tau_{in}^k)^{-\theta^k}}{\sum_{h=1}^{N} T_h^k (w_h \tau_{hn}^k)^{-\theta^k}} \tag{77}$$

Now we derive an equation for expenditure X_n^k. Let I_n denote total income in country n. Given the Cobb-Douglas preferences (68), consumers in country n spend the fraction α_n^k of their income on sector k:

$$X_n^k = \alpha_n^k I_n \tag{78}$$

Income in country n consists of workers' wage income plus firms' profits Y_n plus tariff revenue R_n plus trade deficit D_n:

$$I_n = w_n L_n + Y_n + R_n + D_n \tag{79}$$

where L_n is labor force in country n. Since, by our definition, country i's expenditure in sector k from country n is $X_{ni}^k = \pi_{ni}^k X_i^k$, total revenue of sector k firms in country n from their sale in country i is $\frac{1}{1+t_{ni}^k} \pi_{ni}^k X_i^k$. Moreover, since all these firms charge the same markup $\frac{\sigma_i^k}{\sigma_i^k - 1}$, total revenue of these firms is $\frac{\sigma_i^k}{\sigma_i^k - 1}$ times their total cost. Hence, total profit from selling sector k goods in country i is $\frac{1}{\sigma_i^k (1+t_{ni}^k)} X_{ni}^k$. Therefore, total profit Y_n can be written as

$$Y_n = \sum_{k=1}^{K} \sum_{i=1}^{N} \frac{\pi_{ni}^k X_i^k}{\sigma_i^k (1 + t_{ni}^k)} \tag{80}$$

Imports of country n from i in sector k is $\frac{\pi_{in}^k X_n^k}{1+t_{in}^k}$. Hence, tariff revenue R_n can be written as

$$R_n = \sum_{k=1}^{K} \sum_{i=1}^{N} \frac{t_{in}^k}{(1 + t_{in}^k)} \pi_{in}^k X_n^k \tag{81}$$

As for trade deficits, by definition, total imports minus trade deficit (left-hand side) equals total exports (right-hand side):

$$\sum_{k=1}^{K}\sum_{i=1}^{N}\frac{\pi_{in}^{k}X_{n}^{k}}{(1+t_{in}^{k})}-D_{n}=\sum_{k=1}^{K}\sum_{i=1}^{N}\frac{\pi_{ni}^{k}X_{i}^{k}}{(1+t_{ni}^{k})} \tag{82}$$

It can be shown that trade balance (82) implies labor market clearing. To see that, sum over all sectors k in equation (78), and use the trade balance to write:

$$w_{n}L_{n}=\sum_{k=1}^{K}\sum_{i=1}^{N}\frac{\pi_{ni}^{k}X_{i}^{k}}{(1+t_{ni}^{k})}-Y_{n}=\sum_{k=1}^{K}\sum_{i=1}^{N}\frac{(\sigma_{i}^{k}-1)\pi_{ni}^{k}X_{i}^{k}}{\sigma_{i}^{k}(1+t_{ni}^{k})} \tag{83}$$

C.6 Equilibrium

Equilibrium Definition Given Frećhet location parameters T_n^k and shape parameters θ^k, elasticities of substitution σ_n^k, Cobb-Douglas shares α_n^k, labor endowments L_n, iceberg trade costs d_{in}^k, and Ad Valorem tariffs t_{in}^k, an equilibrium is characterized by a set of wages $\{w_n\}_{n=1}^N$ that satisfy equilibrium conditions (76), (77), (78), (79), (80), (81), and (82).

Instead of solving the model in levels, we solve the model in relative changes using the "hat-algebra" notation in Dekle, Eaton and Kortum (2008). The main advantage of solving the model in relative terms is that we do not need to know the Frećhet location parameters T_n^k and iceberg trade costs d_{in}^k, which simplifies the analysis substantially. Define the vector of trade frictions as $\tau \equiv \{\tau_{in}^k\}_{i=1,n=1,k=1}^{N,N,K}$. Let x' and x denote a variable under a counterfactual trade friction τ' and the actual trade friction τ, respectively. Define $\hat{x} = x'/x$. Now we express the equilibrium conditions stated above in relative terms.

First, divide the price index (76) under τ' by the one under τ, and then use (77) to remove T_n^k:

$$\hat{\mathcal{P}}_{n}^{k}=[\sum_{i=1}^{N}\pi_{in}^{k}(\hat{w}_{i}\hat{\tau}_{in}^{k})^{-\theta^{k}}]^{\frac{-1}{\theta^{k}}} \tag{84}$$

Then, we use the price index (76) in the trade shares (77) to write the trade shares in relative terms:

$$\hat{\pi}_{in}^{k}=[\frac{\hat{w}_{i}\hat{\tau}_{in}^{k}}{\hat{\mathcal{P}}_{n}^{k}}]^{-\theta^{k}} \tag{85}$$

Next, we write total expenditure (78) under the counterfactual trade frictions:

$$X_{n}^{\prime k}=\alpha_{n}^{k}I_{n}^{\prime} \tag{86}$$

Using income equation (79), we can write income under counterfactual trade frictions as follows:

$$I'_n = \hat{w}_n w_n L_n + Y'_n + R'_n + D_n \tag{87}$$

where

$$Y'_n = \sum_{k=1}^{K}\sum_{i=1}^{N} \frac{\pi'^k_{ni} X'^k_i}{\sigma^k_i (1 + t'^k_{ni})} \tag{88}$$

$$R'_n = \sum_{k=1}^{K}\sum_{i=1}^{N} \frac{t'^k_{in}}{(1 + t'^k_{in})} \pi'^k_{in} X'^k_n \tag{89}$$

and we assume trade deficits remain unchanged. Similarly, use trade balance equation (82) to write trade balance under counterfactual trade frictions

$$\sum_{k=1}^{K}\sum_{i=1}^{N} \frac{\pi'^k_{in} X'^k_n}{(1 + t'^k_{in})} - D_n = \sum_{k=1}^{K}\sum_{i=1}^{N} \frac{\pi'^k_{ni} X'^k_i}{(1 + t'^k_{ni})} \tag{90}$$

where we again assume trade deficits remain unchanged.

Equilibrium Definition in Relative Terms Given Fréchet shape parameters θ^k, elasticities of substitution σ^k_n, Cobb-Douglas shares α^k_n, total expenditures X^k_n, trade shares π^k_{in}, labor endowments L_n, relative trade frictions $\hat{\tau}^k_{in}$, and Ad Valorem tariffs t'^k_{in}, an equilibrium is characterized by a set of relative wages $\{\hat{w}_n\}_{n=1}^N$ that satisfy equilibrium conditions (84), (85), (86), (87), (88), (89), and (90).

C.7 Solving for Equilibrium

This section briefly explains how we solve for the equilibrium. The procedure is similar to the one described in Appendix B. The equilibrium objects that we need to solve for are relative changes in trade shares $\hat{\pi}^{j(k)}_{in}$, relative changes in wages $\hat{w}_n$, relative changes in prices $\hat{P}^{j(k)}_n$, and counterfactual expenditures $X'^{j(k)}_n$. The procedure to solve for the equilibrium is as follows.

i) We first make a guess on $\hat{w}_n$.

ii) Compute $\hat{P}^{j(k)}_n$ using equation (84).

iii) Use equation (85) to compute $\hat{\pi}^{j(k)}_{in}$.

iv) Use the system of equations (86)-(89) to solve for counterfactual expenditures $X'^{j(k)}_n$.

v) Check the trade balance equation (90). If it is satisfied, we are done. Otherwise, we update our guess on $\hat{w}_n$ and go back to step (ii).

D Gains from Trade

To numerically compute the gains from trade, we use the equilibrium conditions in relative terms derived in Section 3.6, and move the trade cost between countries to infinity. So we can write the price equation (20) as

$$\hat{P}_n^{j(k)} = [\pi_{nn}^{j(k)}]^{\frac{-1}{\theta^{j(k)}}} \tag{91}$$

Note that as we showed in the text, trade balance and labor market clearing are two sides of the same coin. Since by definition trade is balanced in autarky, labor market also clears at every wage. We set $\hat{w}_n = 1$ for all countries.

To find the expenditures in autarky, we use equation (24) in the text:

$$X_n^{\prime j(k)} = \alpha_n^k I_n^\prime \frac{\hat{P}_n^{j(k)\ 1-\sigma_n^k} X_n^{j(k)}}{\sum_{l=1}^{J(k)} \hat{P}_n^{l(k)\ 1-\sigma_n^k} X_n^{l(k)}} \tag{92}$$

where

$$I_n^\prime = w_n L_n + Y_n^\prime \tag{93}$$

$$Y_n^\prime = \sum_{k=1}^{K} \sum_{j=1}^{J(k)} \frac{X_n^{\prime j(k)}}{\sigma_n^{j(k)}} \tag{94}$$

We solve the system of equations (92)-(94) for the counterfactual expenditures $X_n^{\prime j(k)}$. To do so, we transform this system of linear equations to a matrix form similar to what we did in Appendix B.

After solving for the counterfactual expenditures, we find counterfactual incomes using equation (93). To find counterfactual welfare (i.e., real income), we use the change in sectoral price indices in equation (23):

$$\hat{\mathcal{P}}_n^{k\ 1-\sigma_n^k} = \frac{1}{\alpha_n^k I_n} \sum_{l=1}^{J(k)} \hat{P}_n^{l(k)\ 1-\sigma_n^k} X_n^{l(k)}$$

Table D.1: Gains from Trade: the absolute value of welfare changes (%) as we move from the observed trade data in 2015 to autarky

Countries	Baseline Model				Perfect Competition Model		
	welfare	wage	profit	tariff	welfare	wage	tariff
Australia	14.977	8.701	6.006	0.270	14.913	14.643	0.270
Austria	12.991	7.395	5.421	0.175	13.174	12.998	0.176
Bangladesh	1.426	0.797	0.424	0.205	1.491	1.285	0.206
Belgium	31.018	16.727	13.799	0.492	26.997	26.505	0.492
Brazil	5.333	2.937	1.867	0.529	5.090	4.561	0.529
Canada	39.303	23.086	15.870	0.347	34.599	34.252	0.346
China	2.490	1.478	0.733	0.279	2.615	2.336	0.280
Denmark	26.980	15.275	11.281	0.423	25.551	25.128	0.423
France	15.960	9.922	5.784	0.255	15.219	14.964	0.255
Germany	10.166	7.081	2.850	0.235	11.500	11.264	0.235
Greece	3.840	2.019	1.746	0.075	3.114	3.039	0.075
India	0.728	0.382	0.245	0.101	0.642	0.542	0.101
Indonesia	4.066	2.967	0.793	0.306	5.072	4.765	0.306
Italy	6.263	4.131	2.013	0.119	6.662	6.543	0.119
Japan	0.782	0.702	0.034	0.045	1.097	1.052	0.046
Rep. of Korea	1.840	1.165	0.572	0.103	1.604	1.501	0.103
Mexico	12.814	8.740	3.896	0.178	13.176	12.998	0.178
Netherlands	14.422	7.499	6.651	0.272	13.008	12.736	0.272
New Zealand	14.699	8.882	5.649	0.168	13.148	12.980	0.168
Norway	15.417	9.422	5.646	0.350	16.599	16.249	0.350
Peru	0.879	1.445	0.602	0.036	2.452	2.416	0.036
Romania	6.572	3.361	3.103	0.107	5.224	5.117	0.107
Russia	5.560	3.227	2.077	0.256	5.172	4.916	0.256
Vietnam	11.535	6.353	4.592	0.590	9.036	8.446	0.590
Spain	5.036	2.724	2.214	0.098	5.181	5.082	0.098
Sweden	12.293	4.464	7.698	0.131	11.253	11.122	0.131
Egypt	4.863	2.409	2.189	0.265	4.570	4.305	0.265
United Kingdom	18.371	11.004	7.080	0.286	20.251	19.965	0.286
USA	6.929	3.035	3.815	0.079	6.412	6.333	0.079
ROW	21.821	12.637	8.091	1.092	22.418	21.294	1.124

Notes: The first four columns associate with the baseline model, and the last three columns are associated with the perfect competition model. Columns "welfare" report the percentage change in welfare. Based on the welfare decomposition (30), we decompose the welfare changes into the percentage change in real wages, real profits, and real tariff revenues, reported in columns "wage", "profit", and "tariff", respectively. Numbers are rounded to the nearest thousandth.

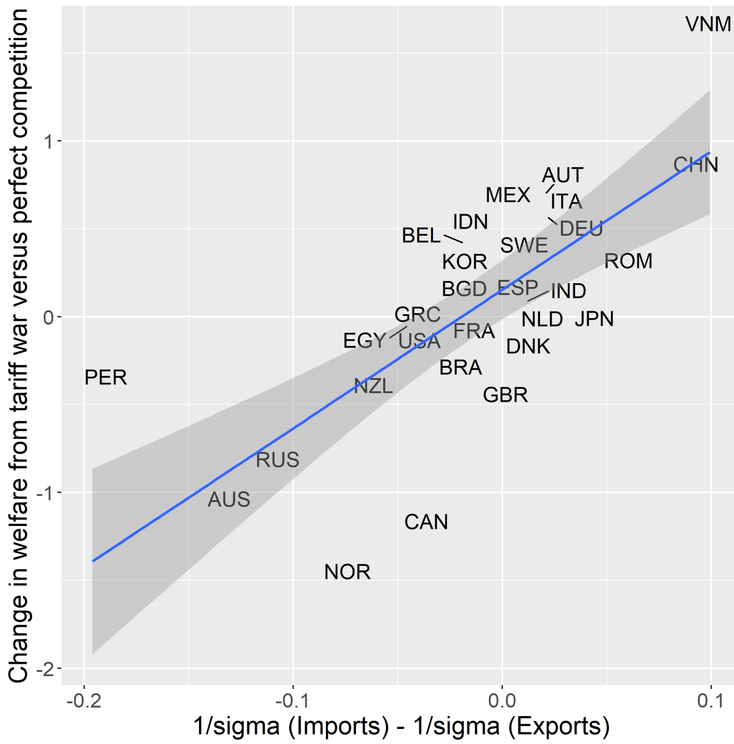
Table D.2: Gains from Trade (Homogeneous Elasticities): the absolute value of welfare changes (%) as we move from the observed trade data in 2015 to autarky

Countries	Baseline Model				Perfect Competition Model		
	welfare	wage	profit	tariff	welfare	wage	tariff
Australia	17.242	7.408	9.563	0.270	12.848	12.578	0.270
Austria	5.783	2.262	3.345	0.176	5.109	4.933	0.176
Bangladesh	1.251	0.496	0.549	0.206	1.313	1.108	0.205
Belgium	26.715	11.891	14.331	0.493	24.411	23.918	0.493
Brazil	2.705	1.918	0.257	0.530	3.635	3.106	0.529
Canada	18.622	11.316	6.967	0.339	20.233	19.895	0.339
China	1.698	1.081	0.338	0.278	2.621	2.342	0.279
Denmark	22.691	12.576	9.692	0.423	22.104	21.680	0.423
France	15.598	6.936	8.407	0.256	13.372	13.116	0.256
Germany	6.703	3.984	2.484	0.235	8.957	8.721	0.236
Greece	1.886	1.301	0.510	0.075	2.626	2.551	0.075
India	0.592	0.226	0.266	0.101	0.631	0.530	0.101
Indonesia	4.086	1.951	1.828	0.306	4.317	4.011	0.306
Italy	2.640	1.717	0.804	0.119	3.912	3.793	0.119
Japan	0.860	0.613	0.201	0.046	1.102	1.057	0.046
Rep. of Korea	0.844	0.615	0.126	0.103	1.334	1.231	0.103
Mexico	11.644	6.032	5.436	0.176	10.857	10.682	0.175
Netherlands	10.749	4.678	5.799	0.272	9.549	9.277	0.272
New Zealand	19.102	6.943	11.990	0.168	12.080	11.912	0.168
Norway	10.526	6.402	3.774	0.350	11.270	10.920	0.349
Peru	3.903	1.593	2.274	0.036	2.455	2.419	0.036
Romania	2.290	1.865	0.318	0.107	3.944	3.837	0.107
Russia	7.279	2.362	4.660	0.257	4.280	4.024	0.256
Vietnam	5.470	4.160	0.719	0.591	8.303	7.711	0.592
Spain	1.445	1.093	0.253	0.099	2.818	2.719	0.099
Sweden	6.588	3.135	3.322	0.131	7.273	7.142	0.131
Egypt	5.519	1.900	3.353	0.266	4.238	3.973	0.265
United Kingdom	12.442	8.591	3.563	0.287	14.844	14.557	0.287
USA	7.036	3.032	3.925	0.079	6.412	6.334	0.079
ROW	19.706	11.246	7.198	1.261	20.387	19.093	1.294

Notes: The first four columns associate with the baseline model, and the last three columns are associated with the perfect competition model. Columns "welfare" report the percentage change in welfare. Based on the welfare decomposition (30), we decompose the welfare changes into the percentage change in real wages, real profits, and real tariff revenues, reported in columns "wage", "profit", and "tariff", respectively. We assume all countries share the same elasticities of substitution as in the U.S. Numbers are rounded to the nearest thousandth.

E Additional Figures and Tables

Figure E.1: Welfare Consequences of the Global Tariff War in the Baseline Model versus Perfect Competition Model: Homogeneous Elasticities



Notes: The horizontal axis measures average import markup minus average export markup for a country, when we assume all countries share the same elasticities of substitution as in the U.S. The vertical axis is percentage changes in welfare in our baseline model minus those in the perfect competition model, when all countries raise all import tariffs by 20 percentage points. The shaded areas reflect linear fitted lines along with their 95% confidence bands.

Table E.1: Inverse Demand Elasticities and Import/Export Shares for selected countries

	Germany				Belgium			
	Imports		Exports		Imports		Exports	
Product Category (HS2 level)	$1/\sigma$	Share	$1/\sigma$	Share	$1/\sigma$	Share	$1/\sigma$	Share
Synthetic Categories	.639	36.59	.421	33.4	.222	38.71	.478	37.31
Vehicles (87)	.406	7.70	.365	16.31	.222	10.4	.396	9.56
Machinery, Mech. Appliances (84)	.430	7.44	.328	11.38	.342	4.99	.345	4.39
Electrical Machinery/Equipment (85)	.409	5.65	.305	5.07	.31	1.85	.359	1.45
Mineral Fuels/Oils, etc. (27)	.314	4.45	.287	.42	.497	7.34	.232	4.08
Plastics and Articles thereof (39)	.408	2.86	.395	3.42	.341	3.43	.409	6.73
Instruments/Apparatus (90)	.360	2.63	.307	3.56	.334	2.04	.364	1.5
Aircraft, Spacecraft (88)	.682	2.58	.637	3.02	.39	.25	.642	.32
Furniture, Bedding, etc. (94)	.378	1.87	.323	1.16	.378	.94	.327	.54n
Clothing Accessories, not knitted (62)	.326	1.66	.342	.48	.135	.89	.41	.42
Iron and Steel Articles (73)	.526	1.51	.419	1.8	.416	.97	.428	.87
Iron and Steel (72)	.386	1.48	.434	.95	.334	1.23	.429	1.83
Aluminium and Articles thereof (76)	.299	1.45	.463	1.02	.411	.78	.369	.71
Clothing Accessories, knitted (61)	.329	1.41	.410	.38	.107	.85	.463	.48
Organic Chemicals (29)	.376	1.37	.417	1.36	.298	4.24	.414	3.46
Rubber and Articles thereof (40)	.301	1.19	.275	.99	.307	.94	.283	1.01
Precious Stones, Pearls (71)	.378	1.16	.543	.83	.159	4.68	.593	6.57
Ores, Slag, and Ash (26)	.400	.71	.457	.03	.532	.74	.377	.22
Fruits and Nuts (8)	.390	.67	.361	.11	.291	.43	.334	.2
Copper and Articles thereof (74)	.439	.67	.416	.7	.297	.64	.451	.68

Notes: Inverse demand elasticity in each HS2 sector is the average of HS6 inverse demand elasticites, weighted by trade volumes.

Table E.2: Inverse Demand Elasticities and Import/Export Shares for selected countries (cont.)

	China			
	Imports		Exports	
Product Category (HS2 level)	$1/\sigma$	Share	$1/\sigma$	Share
Synthetic Categories	.541	35.87	.307	48.38
Vehicles (87)	.374	3.41	.312	1.68
Machinery, Mech. Appliances (84)	.28	3.97	.297	5
Electrical Machinery/Equipment (85)	.346	4.8	.263	8.09
Mineral Fuels/Oils, etc. (27)	.344	11.98	.432	.28
Plastics and Articles thereof (39)	.308	3.53	.294	1.96
Instruments/Apparatus (90)	.299	4.72	.214	2.61
Aircraft, Spacecraft (88)	.575	1.68	.338	.09
Furniture, Bedding, etc. (94)	.387	.2	.303	3.72
Clothing Accessories, not knitted (62)	.297	.21	.402	3.03
Iron and Steel Articles (73)	.358	.5	.418	2.09
Iron and Steel (72)	.329	.64	.426	1.43
Aluminium and Articles thereof (76)	.191	.41	.473	.7
Clothing Accessories, knitted (61)	.263	.11	.457	2.51
Organic Chemicals (29)	.312	2.65	.451	.91
Rubber and Articles thereof (40)	.355	.85	.193	.76
Precious Stones, Pearls (71)	.333	6.24	.495	1.23
Ores, Slag, and Ash (26)	.486	6.13	.417	.01
Fruits and Nuts (8)	.438	.13	.566	.13
Copper and Articles thereof (74)	.369	1.87	.445	.22

Notes: Inverse demand elasticity in each HS2 sector is the average of HS6 inverse demand elasticites, weighted by trade volumes.

Table E.3: Inverse Demand Elasticities and Import/Export Shares for selected countries (Homogeneous Elasticities)

	Germany				Belgium			
	Imports		Exports		Imports		Exports	
Product Category (HS2 level)	$1/\sigma$	Share	$1/\sigma$	Share	$1/\sigma$	Share	$1/\sigma$	Share
Synthetic Categories	.401	36.59	.436	33.40	.511	38.71	.532	37.31
Vehicles (87)	.324	7.70	.331	16.31	.292	10.4	.331	9.56
Machinery, Mech. Appliances (84)	.270	7.44	.251	11.38	.232	4.99	.234	4.39
Electrical Machinery/Equipment (85)	.189	5.65	.202	5.07	.19	1.85	.203	1.45
Mineral Fuels/Oils, etc. (27)	.636	4.45	.476	.42	.548	7.34	.438	4.08
Plastics and Articles thereof (39)	.400	2.86	.404	3.42	.412	3.43	.446	6.73
Instruments/Apparatus (90)	.199	2.63	.201	3.56	.192	2.04	.198	1.5
Aircraft, Spacecraft (88)	.422	2.58	.453	3.02	.387	.25	.253	.32
Furniture, Bedding, etc. (94)	.228	1.87	.222	1.16	.237	.94	.282	.54
Clothing Accessories, not knitted (62)	.381	1.66	.384	.48	.416	.89	.437	.42
Iron and Steel Articles (73)	.469	1.51	.456	1.8	.461	.97	.374	.87
Iron and Steel (72)	.421	1.48	.441	.95	.37	1.23	.45	1.83
Aluminium and Articles thereof (76)	.541	1.45	.563	1.02	.498	.78	.546	.71
Clothing Accessories, knitted (61)	.527	1.41	.517	.38	.521	.85	.543	.48
Organic Chemicals (29)	.530	1.37	.5	1.36	.529	4.24	.496	3.46
Rubber and Articles thereof (40)	.180	1.19	.241	.99	.238	.94	.241	1.01
Precious Stones, Pearls (71)	.410	1.16	.519	.83	.509	4.68	.481	6.57
Ores, Slag, and Ash (26)	.637	.71	.603	.03	.742	.74	.766	.22
Fruits and Nuts (8)	.507	.67	.5	.11	.496	.43	.419	.2
Copper and Articles thereof (74)	.521	.67	.446	.7	.602	.64	.419	.68

Notes: Inverse demand elasticity in each HS2 sector is the average of HS6 inverse demand elasticites, weighted by trade volumes. We assume all countries share the same demand elasticities as in the U.S.

Table E.4: Inverse Demand Elasticities and Import/Export Shares for selected countries (cont., Homogeneous Elasticities)

	China			
	Imports		Exports	
Product Category (HS2 level)	$1/\sigma$	Share	$1/\sigma$	Share
Synthetic Categories	.285	35.87	.227	48.38
Vehicles (87)	.534	3.41	.326	1.68
Machinery, Mech. Appliances (84)	.252	3.97	.249	5.00
Electrical Machinery/Equipment (85)	.170	4.80	.183	8.09
Mineral Fuels/Oils, etc. (27)	.589	11.98	.528	0.28
Plastics and Articles thereof (39)	.487	3.53	.262	1.96
Instruments/Apparatus (90)	.099	4.72	.126	2.61
Aircraft, Spacecraft (88)	.507	1.68	.271	0.09
Furniture, Bedding, etc. (94)	.232	.2	.255	3.72
Clothing Accessories, not knitted (62)	.386	.21	.404	3.03
Iron and Steel Articles (73)	.521	.5	.419	2.09
Iron and Steel (72)	.368	.64	.437	1.43
Aluminium and Articles thereof (76)	.577	.41	.59	0.70
Clothing Accessories, knitted (61)	.530	.11	.506	2.51
Organic Chemicals (29)	.478	2.65	.501	.91
Rubber and Articles thereof (40)	.321	.85	.108	.76
Precious Stones, Pearls (71)	.605	6.24	.464	1.23
Ores, Slag, and Ash (26)	..512	6.13	.464	.01
Fruits and Nuts (8)	.540	.13	.627	.13
Copper and Articles thereof (74)	.568	1.87	.459	.22

Notes: Inverse demand elasticity in each HS2 sector is the average of HS6 inverse demand elasticites, weighted by trade volumes. We assume all countries share the same demand elasticities as in the U.S.

Table E.5: A Global Tariff War (If Trade Elasticities were 50% Larger): welfare changes (%) when all countries raise all tariffs by 20 percentage points

Countries	Baseline Model				Perfect Competition Model		
	welfare	wage	profit	tariff	welfare	wage	tariff
Australia	-0.664	-0.943	-0.416	0.696	-0.893	-1.587	0.694
Austria	-0.711	-0.760	-0.698	0.748	-0.592	-1.340	0.748
Bangladesh	-0.185	-0.148	-0.054	0.017	-0.222	-0.239	0.017
Belgium	-5.716	-2.318	-5.132	1.734	-1.943	-3.730	1.787
Brazil	-0.750	-0.414	-0.416	0.080	-0.563	-0.643	0.080
Canada	-5.591	-2.271	-5.011	1.692	-1.684	-3.428	1.744
China	-0.193	-0.259	-0.080	0.145	-0.265	-0.410	0.145
Denmark	-2.501	-2.158	-2.190	1.847	-1.706	-3.563	1.857
France	-1.436	-1.146	-1.219	0.929	-0.799	-1.734	0.935
Germany	0.149	-0.803	0.137	0.815	-0.463	-1.273	0.810
Greece	-0.830	-0.374	-0.693	0.238	-0.326	-0.565	0.239
India	-0.179	-0.115	-0.084	0.021	-0.143	-0.164	0.021
Indonesia	0.014	-0.634	0.245	0.403	-0.617	-1.017	0.400
Italy	-0.128	-0.480	-0.082	0.434	-0.326	-0.760	0.434
Japan	0.050	-0.149	0.045	0.154	-0.069	-0.223	0.154
Rep. of Korea	-0.297	-0.203	-0.238	0.144	-0.118	-0.262	0.144
Mexico	-0.839	-1.345	-0.802	1.308	-0.687	-2.000	1.313
Netherlands	-1.891	-1.210	-1.718	1.036	-1.016	-2.060	1.044
New Zealand	-1.937	-0.951	-1.651	0.665	-0.725	-1.398	0.673
Norway	-0.390	-1.098	-0.127	0.836	-1.060	-1.891	0.831
Peru	-0.365	-0.185	-0.310	0.129	-0.179	-0.309	0.130
Romania	-0.972	-0.399	-0.956	0.383	-0.226	-0.611	0.385
Russia	-0.779	-0.487	-0.527	0.236	-0.507	-0.743	0.236
Vietnam	-3.130	-1.368	-2.467	0.705	-1.114	-1.833	0.720
Spain	-0.129	-0.296	-0.137	0.303	-0.249	-0.551	0.303
Sweden	-0.766	-0.471	-0.959	0.665	-0.509	-1.175	0.667
Egypt	-0.360	-0.291	-0.184	0.115	-0.406	-0.521	0.115
United Kingdom	0.286	-1.069	0.416	0.939	-0.999	-1.929	0.930
USA	-0.394	-0.299	-0.387	0.292	-0.329	-0.622	0.292
ROW	-0.748	-1.883	-0.557	1.692	-1.520	-3.163	1.643

Notes: The first four columns associate with the baseline model, and the last three columns are associated with the perfect competition model. Columns "welfare" report the percentage change in welfare. Based on the welfare decomposition (30), we decompose the welfare changes into the percentage change in real wages, real profits, and real tariff revenues, reported in columns "wage", "profit", and "tariff", respectively. Numbers are rounded to the nearest thousandth.

Table E.6: A Global Tariff War (Homogeneous Trade Elasticities): welfare changes (%) when all countries raise all tariffs by 20 percentage points

Countries	Baseline Model				Perfect Competition Model		
	welfare	wage	profit	tariff	welfare	wage	tariff
Australia	-0.782	-0.998	-0.754	0.970	-0.713	-1.684	0.971
Austria	-0.473	-0.880	-0.573	0.980	-0.570	-1.549	0.979
Bangladesh	-0.166	-0.183	-0.085	0.102	-0.194	-0.296	0.102
Belgium	-4.467	-2.600	-4.403	2.536	-1.599	-4.190	2.591
Brazil	-0.683	-0.496	-0.449	0.262	-0.508	-0.771	0.262
Canada	-4.510	-2.412	-4.269	2.172	-1.414	-3.632	2.218
China	-0.239	-0.353	-0.145	0.260	-0.299	-0.558	0.259
Denmark	-2.033	-2.388	-2.094	2.448	-1.485	-3.942	2.457
France	-1.268	-1.287	-1.225	1.245	-0.698	-1.950	1.251
Germany	-0.068	-1.001	-0.062	0.995	-0.595	-1.586	0.991
Greece	-0.652	-0.390	-0.649	0.387	-0.201	-0.590	0.389
India	-0.171	-0.141	-0.126	0.097	-0.104	-0.201	0.097
Indonesia	-0.087	-0.767	-0.010	0.690	-0.543	-1.231	0.688
Italy	-0.175	-0.580	-0.192	0.597	-0.321	-0.918	0.597
Japan	-0.021	-0.194	-0.015	0.188	-0.102	-0.291	0.188
Rep. of Korea	-0.293	-0.258	-0.235	0.200	-0.133	-0.333	0.200
Mexico	-1.119	-1.655	-0.965	1.501	-0.960	-2.466	1.506
Netherlands	-1.547	-1.402	-1.629	1.485	-0.895	-2.389	1.493
New Zealand	-1.386	-0.940	-1.310	0.864	-0.509	-1.378	0.870
Norway	-0.080	-1.182	-0.135	1.237	-0.799	-2.029	1.230
Peru	-0.199	-0.184	-0.210	0.195	-0.113	-0.308	0.195
Romania	-0.953	-0.458	-0.960	0.465	-0.233	-0.701	0.467
Russia	-0.630	-0.554	-0.520	0.444	-0.401	-0.845	0.444
Vietnam	-2.564	-1.548	-2.109	1.093	-0.968	-2.077	1.109
Spain	-0.061	-0.335	-0.124	0.398	-0.228	-0.625	0.398
Sweden	-0.445	-0.531	-0.771	0.857	-0.467	-1.325	0.857
Egypt	-0.180	-0.254	-0.148	0.222	-0.232	-0.453	0.221
United Kingdom	0.325	-1.075	0.158	1.242	-0.704	-1.939	1.234
USA	-0.204	-0.277	-0.304	0.378	-0.198	-0.576	0.378
ROW	-0.883	-2.040	-1.090	2.247	-1.209	-3.435	2.226

Notes: The first four columns associate with the baseline model, and the last three columns are associated with the perfect competition model. Columns "welfare" report the percentage change in welfare. Based on the welfare decomposition (30), we decompose the welfare changes into the percentage change in real wages, real profits, and real tariff revenues, reported in columns "wage", "profit", and "tariff", respectively. We assume trade elasticity in all sectors is 3.69, which is the median trade elasticities that we estimated in Section 5. Numbers are rounded to the nearest thousandth.

Table E.7: Welfare changes (%) when the U.S. unilaterally raises all tariffs by 20 percentage points

Countries	Baseline Model				Perfect Competition Model		
	welfare	wage	profit	tariff	welfare	wage	tariff
Australia	-0.047	-0.051	-0.001	0.004	-0.081	-0.085	0.004
Austria	-0.010	-0.023	0.017	-0.004	-0.044	-0.040	-0.004
Bangladesh	-0.023	-0.008	-0.011	-0.004	-0.016	-0.012	-0.004
Belgium	-0.336	-0.092	-0.212	-0.032	-0.183	-0.151	-0.031
Brazil	-0.117	-0.032	-0.061	-0.024	-0.074	-0.050	-0.024
Canada	-2.565	-0.862	-1.668	-0.035	-1.345	-1.313	-0.033
China	-0.000	-0.026	0.036	-0.010	-0.051	-0.041	-0.010
Denmark	-0.155	-0.057	-0.090	-0.008	-0.104	-0.097	-0.007
France	-0.069	-0.047	-0.015	-0.007	-0.078	-0.071	-0.007
Germany	-0.022	-0.039	0.024	-0.006	-0.068	-0.062	-0.006
Greece	-0.002	-0.005	0.003	-0.000	-0.007	-0.007	-0.000
India	-0.019	-0.007	-0.009	-0.004	-0.013	-0.010	-0.004
Indonesia	-0.026	-0.029	0.012	-0.009	-0.056	-0.047	-0.009
Italy	-0.001	-0.017	0.018	-0.003	-0.029	-0.026	-0.003
Japan	-0.005	-0.013	0.010	-0.003	-0.022	-0.019	-0.003
Rep. of Korea	-0.020	-0.015	-0.003	-0.002	-0.021	-0.019	-0.002
Mexico	-0.702	-0.529	-0.171	-0.003	-0.789	-0.786	-0.003
Netherlands	-0.098	-0.044	-0.043	-0.010	-0.086	-0.075	-0.010
New Zealand	-0.124	-0.063	-0.054	-0.006	-0.100	-0.093	-0.006
Norway	-0.034	-0.037	0.003	-0.000	-0.063	-0.063	-0.000
Peru	-0.061	-0.019	-0.041	-0.001	-0.032	-0.031	-0.001
Romania	0.003	-0.004	0.007	-0.001	-0.006	-0.006	-0.001
Russia	-0.050	-0.018	-0.028	-0.005	-0.032	-0.027	-0.005
Vietnam	-0.137	-0.087	-0.035	-0.014	-0.131	-0.117	-0.015
Spain	-0.021	-0.007	-0.012	-0.002	-0.015	-0.014	-0.002
Sweden	-0.010	-0.010	0.001	-0.002	-0.026	-0.024	-0.002
Egypt	-0.014	-0.008	-0.003	-0.003	-0.018	-0.015	-0.003
United Kingdom	0.001	-0.056	0.064	-0.008	-0.108	-0.100	-0.008
USA	0.264	-0.185	-0.095	0.544	0.158	-0.384	0.543
ROW	-0.221	-0.128	-0.084	-0.010	-0.226	-0.216	-0.010

Notes: The first four columns associate with the baseline model, and the last three columns are associated with the perfect competition model. Columns "welfare" report the percentage change in welfare. Based on the welfare decomposition (30), we decompose the welfare changes into the percentage change in real wages, real profits, and real tariff revenues, reported in columns "wage", "profit", and "tariff", respectively. Numbers are rounded to the nearest thousandth.

Table E.8: A Global Tariff War (using the HS2 model): welfare changes (%) when all countries raise all tariffs by 20 percentage points

Countries	Baseline Model				Perfect Competition Model		
	welfare	wage	profit	tariff	welfare	wage	tariff
Australia	-0.142	-1.420	0.107	1.171	-0.930	-2.095	1.165
Austria	-1.080	-1.318	-1.227	1.465	-0.812	-2.280	1.468
Bangladesh	-0.188	-0.232	-0.048	0.092	-0.247	-0.339	0.092
Belgium	-1.769	-3.211	-1.168	2.610	-2.094	-4.696	2.602
Brazil	-0.212	-0.529	-0.008	0.325	-0.602	-0.926	0.324
Canada	-4.949	-3.215	-3.973	2.240	-1.813	-4.108	2.295
China	-0.596	-0.511	-0.444	0.358	-0.290	-0.652	0.362
Denmark	0.569	-2.809	0.641	2.737	-1.686	-4.379	2.693
France	-1.048	-1.667	-0.909	1.527	-0.892	-2.423	1.531
Germany	-0.302	-1.219	-0.317	1.234	-0.486	-1.721	1.235
Greece	0.686	-0.482	0.692	0.476	-0.414	-0.885	0.471
India	-0.191	-0.235	-0.059	0.102	-0.218	-0.321	0.103
Indonesia	1.460	-0.829	1.508	0.781	-0.652	-1.423	0.771
Italy	2.691	-0.615	2.514	0.792	-0.385	-1.162	0.777
Japan	0.203	-0.228	0.173	0.258	-0.074	-0.333	0.258
Rep. of Korea	-0.114	-0.331	-0.083	0.299	-0.157	-0.458	0.301
Mexico	-0.932	-1.454	-1.064	1.587	-0.522	-2.116	1.594
Netherlands	-1.436	-1.580	-1.496	1.640	-1.054	-2.703	1.649
New Zealand	-0.778	-1.243	-0.601	1.066	-0.752	-1.818	1.067
Norway	-1.096	-1.604	-0.702	1.209	-1.187	-2.395	1.208
Peru	0.080	-0.271	0.129	0.221	-0.196	-0.417	0.221
Romania	-0.318	-0.674	-0.329	0.685	-0.273	-0.959	0.686
Russia	-0.022	-0.802	0.225	0.555	-0.641	-1.195	0.554
Vietnam	-2.041	-1.932	-1.369	1.259	-1.169	-2.442	1.273
Spain	-0.295	-0.678	-0.194	0.577	-0.324	-0.902	0.578
Sweden	-0.505	-0.989	-0.443	0.928	-0.498	-1.425	0.928
Egypt	0.909	-0.337	1.033	0.212	-0.523	-0.727	0.205
United Kingdom	0.784	-1.457	0.821	1.420	-1.124	-2.521	1.398
USA	0.040	-0.525	0.090	0.475	-0.395	-0.870	0.475
ROW	-2.583	-2.641	-2.029	2.087	-1.279	-3.455	2.177

Notes: The first four columns associate with the baseline model, and the last three columns are associated with the perfect competition model. Columns "welfare" report the percentage change in welfare. Based on the welfare decomposition (30), we decompose the welfare changes into the percentage change in real wages, real profits, and real tariff revenues, reported in columns "wage", "profit", and "tariff", respectively. The results are based on the HS2 model developed in Appendix C. Numbers are rounded to the nearest thousandth.

Table E.9: A Global Tariff War: welfare changes (%) when all countries raise all tariffs by 20 percentage points (elasticities are not winsorized)

Countries	Baseline Model				Perfect Competition Model		
	welfare	wage	profit	tariff	welfare	wage	tariff
Australia	-0.626	-1.051	-0.544	0.968	-0.799	-1.765	0.966
Austria	-0.601	-0.847	-0.724	0.970	-0.521	-1.491	0.970
Bangladesh	-0.150	-0.165	-0.069	0.084	-0.182	-0.266	0.084
Belgium	-4.929	-2.599	-4.627	2.297	-1.823	-4.177	2.354
Brazil	-0.621	-0.458	-0.408	0.244	-0.466	-0.710	0.245
Canada	-4.096	-1.991	-4.651	2.546	-0.412	-3.008	2.596
China	-0.159	-0.287	-0.128	0.256	-0.197	-0.453	0.256
Denmark	-2.175	-2.403	-2.209	2.437	-1.512	-3.960	2.448
France	-1.257	-1.292	-1.197	1.232	-0.713	-1.952	1.239
Germany	0.035	-0.898	-0.104	1.037	-0.389	-1.423	1.034
Greece	-0.727	-0.437	-0.639	0.348	-0.305	-0.655	0.350
India	-0.161	-0.136	-0.089	0.064	-0.128	-0.193	0.064
Indonesia	-0.018	-0.714	0.082	0.615	-0.533	-1.144	0.612
Italy	-0.056	-0.539	-0.097	0.579	-0.272	-0.851	0.579
Japan	0.027	-0.169	-0.001	0.197	-0.056	-0.253	0.197
Rep. of Korea	-0.243	-0.226	-0.217	0.200	-0.091	-0.292	0.201
Mexico	-0.713	-1.521	-0.817	1.625	-0.627	-2.256	1.630
Netherlands	-1.666	-1.354	-1.712	1.400	-0.897	-2.307	1.409
New Zealand	-1.718	-1.050	-1.548	0.881	-0.646	-1.535	0.890
Norway	-0.366	-1.217	-0.318	1.169	-0.926	-2.091	1.164
Peru	0.375	-0.203	0.396	0.182	-0.158	-0.340	0.182
Romania	-0.991	-0.411	-1.065	0.485	-0.142	-0.630	0.488
Russia	-0.692	-0.539	-0.543	0.391	-0.427	-0.818	0.391
Vietnam	-2.467	-1.461	-2.038	1.032	-0.909	-1.956	1.046
Spain	-0.096	-0.336	-0.162	0.402	-0.225	-0.626	0.401
Sweden	-0.470	-0.524	-0.806	0.860	-0.441	-1.303	0.862
Egypt	-0.382	-0.337	-0.256	0.211	-0.390	-0.601	0.211
United Kingdom	0.115	-1.202	0.067	1.249	-0.924	-2.165	1.241
USA	-0.326	-0.346	-0.368	0.388	-0.330	-0.718	0.388
ROW	-0.900	-2.133	-0.939	2.172	-1.431	-3.567	2.137

Notes: The first four columns associate with the baseline model, and the last three columns are associated with the perfect competition model. Columns "welfare" report the percentage change in welfare. Based on the welfare decomposition (30), we decompose the welfare changes into the percentage change in real wages, real profits, and real tariff revenues, reported in columns "wage", "profit", and "tariff", respectively. Elasticities of substitution are not winsorized. Numbers are rounded to the nearest thousandth.

Table E.10: Tariffs, Inverse Elasticities and Import/Export Shares for the U.S.-China Trade War

Product Category (HS2 level)	U.S.				China			
	Share	$1/\sigma_{Im}$	$1/\sigma_{Ex}$	Tariff	Share	$1/\sigma_{Im}$	$1/\sigma_{Ex}$	Tariff
Synthetic Categories	54.58	.197	.443	18.97	39.65	.443	0.197	17.93
Elec. Machinery/Equipment (85)	6.47	.181	.31	18.53	3.18	.31	0.181	22.79
Furniture, Bedding, etc. (94)	6.06	.238	.406	19.79	.26	.406	0.238	17.63
Machinery, Mech. Appliances (84)	4.53	.266	.339	21.68	6.18	.339	0.266	11.19
Cloth. Accessories, not knitted (62)	2.95	.407	.267	14.52	.01	.267	0.407	24.74
Cloth. Accessories, knitted (61)	2.49	.480	.294	14.57	.01	.294	0.480	25.02
Plastics and Articles thereof (39)	2.22	.209	.308	15.70	3.24	.308	0.209	13.81
Iron and Steel Articles (73)	1.88	.483	.349	20.48	.65	.349	0.483	19.06
Instruments/Apparatus (90)	1.83	.191	.256	16.49	4.67	.256	0.191	11.70
Articles of Leather (42)	1.82	.316	.398	25.00	.01	.398	0.316	25.71
Toys, Games, etc. (95)	1.59	.212	.387	8.32	.06	.387	0.212	16.01
Vehicles (87)	1.57	.358	.373	22.87	8.14	.373	0.358	34.12
Textiles, made up articles, rags (63)	1.02	.496	.257	9.19	.01	.257	0.496	20.02
Metal, miscellaneous products (83)	1.02	.600	.402	19.25	.11	.402	0.600	19.53
Rubber and Articles thereof (40)	.7	.120	.304	24.04	.7	.304	0.120	12.84
Tools, Cutlery, etc. (82)	.66	.193	.441	20.63	.16	.441	0.193	21.51
Precious Stones, Pearls (71)	.65	.225	.337	9.66	4.05	.337	0.225	20.15
Miscellaneous mfg. articles (96)	.6	.206	.438	8.22	.04	.438	0.206	19.94
Organic Chemicals (29)	.59	.507	.279	11.28	1.42	.281	0.507	17.89
Paper, Paperboard (48)	.49	.512	.41	23.95	.07	.41	0.512	25.92

Table E.11: U.S.-China Counterfactual Tariff War: welfare changes (%) when U.S. and China raise all tariffs against each other by 20 percentage points

Countries	Baseline Model				Perfect Competition Model		
	welfare	wage	profit	tariff	welfare	wage	tariff
Australia	-0.004	-0.001	-0.004	0.000	-0.002	-0.002	0.000
Austria	-0.001	0.001	-0.002	0.000	0.002	0.001	0.000
Bangladesh	0.001	0.000	0.000	0.000	0.001	0.001	0.000
Belgium	-0.000	0.001	-0.002	0.000	0.002	0.002	0.000
Brazil	-0.000	0.001	-0.001	0.000	0.001	0.001	0.000
Canada	0.006	0.006	-0.001	0.001	0.011	0.010	0.001
China	0.030	-0.046	0.054	0.021	-0.051	-0.072	0.021
Denmark	0.003	0.002	-0.000	0.001	0.005	0.004	0.001
France	0.007	0.003	0.004	0.000	0.005	0.004	0.000
Germany	0.001	0.002	-0.002	0.000	0.003	0.003	0.000
Greece	0.000	0.000	0.000	0.000	0.000	0.000	0.000
India	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Indonesia	-0.001	0.001	-0.002	-0.000	0.002	0.002	-0.000
Italy	-0.001	0.001	-0.002	0.000	0.001	0.001	0.000
Japan	0.000	0.001	-0.001	0.000	0.001	0.001	0.000
Rep. of Korea	0.001	0.001	0.000	0.000	0.001	0.001	0.000
Mexico	0.002	0.013	-0.012	0.001	0.020	0.019	0.001
Netherlands	0.002	0.001	0.000	0.000	0.003	0.002	0.000
New Zealand	-0.010	-0.001	-0.010	-0.000	-0.001	-0.001	-0.000
Norway	0.002	0.001	0.001	0.000	0.002	0.002	0.000
Peru	0.001	-0.000	0.001	0.000	-0.000	-0.000	0.000
Romania	-0.000	0.000	-0.001	0.000	0.000	0.000	0.000
Russia	0.001	0.000	0.001	-0.000	0.000	0.001	-0.000
Vietnam	0.004	0.006	-0.003	0.001	0.009	0.008	0.001
Spain	0.001	0.000	0.000	0.000	0.001	0.001	0.000
Sweden	-0.000	0.001	-0.001	0.000	0.002	0.001	0.000
Egypt	0.001	0.000	0.000	0.000	0.001	0.000	0.000
United Kingdom	-0.001	0.002	-0.003	0.000	0.004	0.003	0.000
USA	-0.125	-0.057	-0.139	0.070	-0.048	-0.119	0.070
ROW	0.004	0.003	0.001	0.000	0.006	0.005	0.000

Notes: The first four columns associate with the baseline model, and the last three columns are associated with the perfect competition model. Columns "welfare" report the percentage change in welfare. Based on the welfare decomposition (30), we decompose the welfare changes into the percentage change in real wages, real profits, and real tariff revenues, reported in columns "wage", "profit", and "tariff", respectively. Numbers are rounded to the nearest thousandth.

Table E.12: The Factual U.S.-China Tariff War (Homogeneous Elasticities): welfare changes (%) given the observed U.S.-China tariff war

Countries	Baseline Model				Perfect Competition Model		
	welfare	wage	profit	tariff	welfare	wage	tariff
Australia	-0.003	-0.002	-0.002	0.000	-0.003	-0.003	0.000
Austria	0.001	0.001	-0.000	0.000	0.001	0.001	0.000
Bangladesh	0.002	0.000	0.001	0.000	0.001	0.001	0.000
Belgium	0.001	-0.000	0.001	-0.000	0.000	0.000	-0.000
Brazil	0.001	0.000	0.000	0.000	0.001	0.001	0.000
Canada	-0.004	0.004	-0.009	0.001	0.009	0.008	0.001
China	0.096	-0.030	0.109	0.017	-0.047	-0.064	0.017
Denmark	0.007	0.002	0.004	0.001	0.004	0.004	0.001
France	0.003	0.001	0.001	0.000	0.002	0.002	0.000
Germany	0.001	0.001	0.000	0.000	0.003	0.003	0.000
Greece	0.000	0.000	0.000	0.000	0.000	0.000	0.000
India	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Indonesia	-0.002	0.001	-0.002	-0.000	0.002	0.002	-0.000
Italy	-0.000	0.001	-0.001	0.000	0.001	0.001	0.000
Japan	0.001	0.001	0.000	0.000	0.001	0.001	0.000
Rep. of Korea	0.000	0.000	-0.000	0.000	0.001	0.001	0.000
Mexico	-0.001	0.011	-0.013	0.001	0.022	0.021	0.001
Netherlands	0.003	0.001	0.002	0.000	0.002	0.002	0.000
New Zealand	-0.000	-0.001	0.001	-0.000	-0.001	-0.001	-0.000
Norway	0.002	0.001	0.001	0.000	0.002	0.002	0.000
Peru	-0.001	-0.000	-0.001	0.000	-0.000	-0.000	0.000
Romania	-0.000	0.000	-0.000	0.000	0.001	0.000	0.000
Russia	0.001	0.000	0.001	-0.000	-0.000	0.000	-0.000
Vietnam	-0.005	0.005	-0.011	0.000	0.009	0.009	0.001
Spain	0.001	0.000	0.001	0.000	0.001	0.001	0.000
Sweden	0.001	0.001	-0.000	0.000	0.002	0.001	0.000
Egypt	0.000	0.000	-0.000	0.000	0.001	0.000	0.000
United Kingdom	0.002	0.001	0.000	0.000	0.003	0.002	0.000
USA	-0.169	-0.050	-0.184	0.065	-0.041	-0.106	0.065
ROW	-0.006	0.003	-0.009	-0.000	0.005	0.004	0.000

Notes: The first four columns associate with the baseline model, and the last three columns are associated with the perfect competition model. Columns "welfare" report the percentage change in welfare. Based on the welfare decomposition (30), we decompose the welfare changes into the percentage change in real wages, real profits, and real tariff revenues, reported in columns "wage", "profit", and "tariff", respectively. We assume all countries share the same elasticities of substitution as in the U.S. Numbers are rounded to the nearest thousandth.

Table E.13: A Counterfactual U.S.-China Tariff War: welfare changes (%) when the U.S. imposes tariffs on high-markup sectors, while China imposes factual tariffs observed in the U.S.-China tariff war.

Countries	Baseline Model				Perfect Competition Model		
	welfare	wage	profit	tariff	welfare	wage	tariff
Australia	0.001	0.004	-0.002	-0.000	0.006	0.006	-0.000
Austria	0.002	0.000	0.001	0.000	0.000	0.000	0.000
Bangladesh	-0.001	-0.000	0.000	-0.000	-0.001	-0.001	-0.000
Belgium	0.005	0.004	0.000	0.002	0.008	0.006	0.002
Brazil	0.004	0.001	0.001	0.001	0.003	0.002	0.001
Canada	0.005	0.011	-0.005	-0.001	0.014	0.015	-0.001
China	-0.074	-0.031	-0.064	0.021	-0.028	-0.049	0.021
Denmark	-0.002	-0.000	-0.002	-0.000	-0.000	-0.000	-0.000
France	-0.001	0.001	-0.002	0.000	0.001	0.001	0.000
Germany	0.000	0.001	-0.001	0.000	0.002	0.002	0.000
Greece	-0.001	-0.000	-0.001	-0.000	-0.000	-0.000	-0.000
India	-0.000	-0.000	-0.000	0.000	0.000	-0.000	0.000
Indonesia	-0.002	0.000	-0.002	0.000	0.001	0.000	0.000
Italy	0.001	0.000	0.001	0.000	0.000	0.000	0.000
Japan	0.001	0.001	0.000	0.000	0.001	0.001	0.000
Rep. of Korea	0.003	0.001	0.002	0.000	0.002	0.002	0.000
Mexico	0.007	-0.000	0.009	-0.001	-0.002	-0.001	-0.001
Netherlands	0.002	0.001	0.000	0.000	0.003	0.002	0.000
New Zealand	0.020	0.003	0.016	0.001	0.006	0.005	0.001
Norway	-0.002	0.001	-0.003	-0.000	0.001	0.002	-0.000
Peru	-0.001	0.001	-0.001	0.000	0.001	0.001	0.000
Romania	0.000	-0.000	0.000	-0.000	-0.000	-0.000	-0.000
Russia	0.000	0.001	-0.001	0.000	0.001	0.001	0.000
Vietnam	0.009	-0.002	0.011	0.000	-0.002	-0.002	0.000
Spain	-0.000	0.000	-0.000	-0.000	0.000	0.000	-0.000
Sweden	0.000	0.000	-0.000	0.000	0.001	0.001	0.000
Egypt	-0.001	0.000	-0.001	-0.000	-0.000	0.000	-0.000
United Kingdom	-0.006	0.001	-0.007	0.000	0.002	0.002	0.000
USA	-0.020	-0.041	0.001	0.021	-0.065	-0.085	0.021
ROW	-0.003	0.005	-0.008	-0.000	0.009	0.008	0.000

Notes: The first four columns associate with the baseline model, and the last three columns are associated with the perfect competition model. Columns "welfare" report the percentage change in welfare. Based on the welfare decomposition (30), we decompose the welfare changes into the percentage change in real wages, real profits, and real tariff revenues, reported in columns "wage", "profit", and "tariff", respectively. Numbers are rounded to the nearest thousandth.