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

Hamid Firooz† — University of Rochester

Gunnar Heins‡ — University of Florida

This version: February 2022

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 liberalization 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 36,000 distinct sector-country pairs and incorporate them into our quantitative 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.

JEL Codes: F12, F14

Keywords: Profit shifting, imperfect competition, markup, trade war, gains from trade

*We are grateful to Jonathan Eaton, Sam Kortum, Anson Soderbery, Jim Tybout, Mike Waugh, and Steve Yeaple for insightful comments, and to our discussants Ahmad Lashkaripour and Jiatong Zhong for fruitful discussions. We also thank Jonathan Adams, David Argente, Felipe Benguria, Elias Dinopoulos, Farid Farrokhi, Doireann Fitzgerald, Kala Krishna, Fernando Parro, Eugenio Rojas, Sebastian Sotelo, Daniel Xu, Steve Yeaple, and seminar participants at Penn State, University of Florida, Virtual International Trade and Macro Seminar, Society for Economic Dynamics, Southeastern International/Development Economics Workshop at Atlanta Fed, Econometric Society European Meeting, Midwest Economic Association, and Southern Economic Association for comments and suggestions. All errors are our own.

†Email address: hfirooz@ur.rochester.edu

‡Email address: gheins@ufl.edu

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.[1] Further, as the role of market power across the world is becoming more and more important (De Loecker and Eeckhout, 2018; De Loecker, Eeckhout and Unger, 2020) and predominantly large firms engage in trade (Freund and Pierola, 2015; Gaubert and Itskhoki, 2021), 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 previous work 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, determined by the elasticity of substitution σ between varieties (which also equals the demand elasticity). 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.

[1]See for example https://www.theguardian.com/global-development/2014/dec/18/developing-countries-debt-eurodad-report. Note that the phrase "profit shifting" is used in two different strands of literature with differing meanings. In the International Macro/Finance literature, profit shifting is typically defined as the practice of business owners transferring money to "tax heavens" to avoid paying taxes. In International Trade however, profit shifting tends to refer to cases where, due to comparative advantage, profits from producing some goods or services shift from producers in one country to those in another country (see e.g., Ossa, 2014). In this paper, profit shifting refers to the latter.

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 is particularly important when productivity differentials between countries are small, i.e. when 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 4-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 specialization 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 36,000 distinct sector- and country-specific elasticities σ. Further, our structural model delivers an estimation equation which allows us to quantify 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 1.7% 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 about 4% compared to 1.6% and 1.7%, respectively, in the perfect competition case. On the other hand, welfare losses in countries like the U.K. and Indonesia 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 e.g. 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 0.41% in the baseline model compared to only 0.34% 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, e.g. 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 2.5% in the homogeneous elasticity case and 4.4% 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, Bangladesh, 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. 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 more than twice as high in a setting with imperfect competition and equal about 0.07 % compared to 0.03% 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 a small welfare gain of 0.01% for the U.S. and a sizable 0.12% loss 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; Costinot and Rodríguez-Clare, 2014; 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).

Second, our paper relates to the literature on profit shifting (see e.g. Spencer and Brander, 1983; Brander and Spencer, 1985; Brander, 1986; Krugman, 1987; Bagwell and Staiger, 2012; Ossa, 2014; Lashkaripour and Lugovskyy, 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. Our paper differs from Lashkaripour and Lugovskyy (2018), as we allow markups and profits to be both sector- and market-specific which has important welfare implications of trade.[2]

In contrast to Ossa (2014), we study profit shifting in a setting with within-sector productivity heterogeneity and cross-country heterogeneity in import demand elasticities. We show that import demand elasticities are both statistically and economically different across countries, and that imposing the same import demand elasticities across countries would markedly change the cross-country pattern of export and import markups as well as the welfare con-

[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.

sequences of trade. Furthermore, since Ossa (2014) employs an Armington-type framework, markups and trade elasticities are tightly connected and trade elasticities equal $\sigma - 1$, which imposes that trade elasticities are comparably lower in high-markup sectors. As a result, trade in high-markup sectors would not respond much to tariffs, which limits the role of profit shifting. To overcome this potential limitation, we develop a new model by incorporating markups into an EK-type framework to be able to disentangle markups from trade elasticities. Indeed, while the correlation between demand elasticities and trade elasticities is 100% in Ossa (2014), our estimates show that they are weakly correlated (if anything), with the correlation coefficient ranging from -6% to 7% for our sample countries. Therefore, profit shifting in our framework plays a quantitatively more important role; In fact, we show that imposing trade elasticities to be $\sigma - 1$ substantially reduces profit shifting, which has a quantitatively large impact on welfare consequences of trade.

To the best of our knowledge, our paper is the first one that provides a detailed and rigorous assessment of how variation in demand elasticities and trade elasticities across sectors jointly determine the welfare implications of trade. 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 aggregate share of profit is generally not constant in our framework.

Third, our paper contributes to the literature on the U.S.-China trade war of 2018 and beyond (see e.g. Fajgelbaum et al., 2020; Amiti, Redding and Weinstein, 2019; Waugh, 2019; Flaaen and Pierce, 2019; Benguria and Saffie, 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.

Finally, 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; Caliendo and Parro, 2015). In contrast to these studies, we estimate both elasticities for the universe of 4-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.

The remainder of the paper is organized as follows. Section 2 documents the cross-country heterogeneity in import demand elasticities to motivate the paper. Section 3 illustrates the main mechanism of the paper using a simple 2-country, 2-sector model. Section 4 develops a quantitative multi-sector trade model with imperfect product markets and sector- and country-specific markups. 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

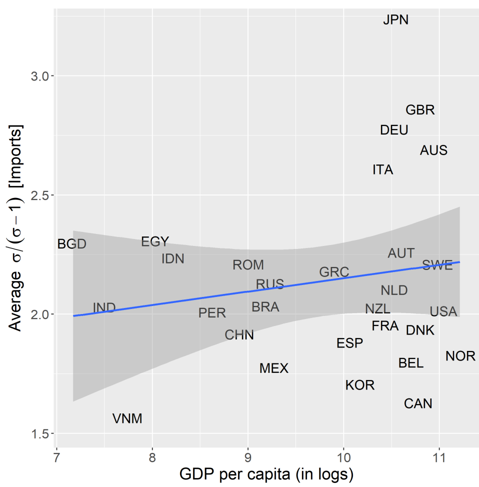
In this section, we first provide suggestive evidence that the goods which countries export and import vary systematically in terms of their demand elasticity and hence in their optimal markups. Specifically, we show that richer countries on average tend to export and import higher-markup goods while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

As described in more detail in Section 5, we begin by estimating the import demand elasticity σ for each of over thousand categories of goods (sectors, hereafter), as defined by their 4-digit Harmonized System codes (HS4). 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 their corresponding demand may differ across countries. We then match the estimated sector- and country-specific elasticities to data on imports and exports of each country in 2015.

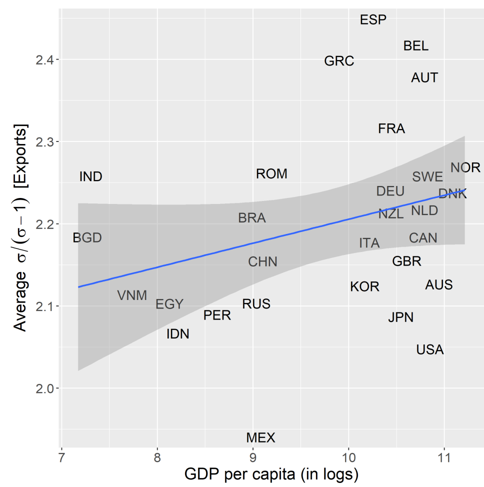
Figure 1 summarizes our estimates and plots the average optimal CES markup $\sigma/(\sigma-1)$ for each country's exports and imports, weighted by trade volumes. As shown in Figure 1a, we find that richer economies tend to import goods with, on average, lower demand elasticities σ. For the richest economies, the average markup takes values in the range between 2.5 and 3.5, while the poorest economies we consider, Vietnam, Bangladesh, and India, import goods with markups between 1.5 and 2.3. In addition, richer countries also tend to export higher-markup goods than poorer countries do and the pattern we saw for imports is qualitatively similar for exports. Also here for example, exports from Vietnam, Indonesia and Mexico tend to be on average lower-markup goods compared to those originating in Belgium, Austria, and Spain.[3]

[3]Most values for the average markup range between 2 and 2.5. Both the level as well as the dispersion of these estimates are consistent with data on markups as e.g. obtained via the methodology developed by De Loecker

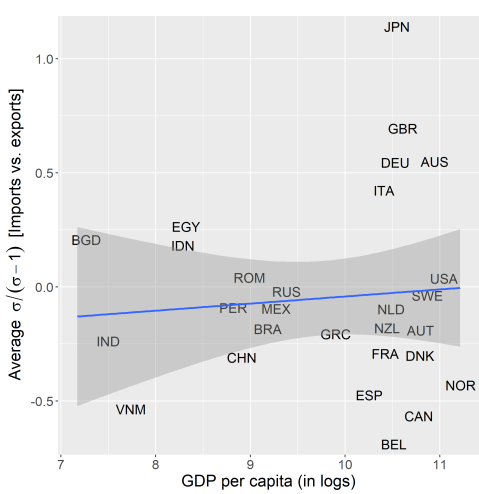
Figure 1: Average CES Markup for Imports and Exports



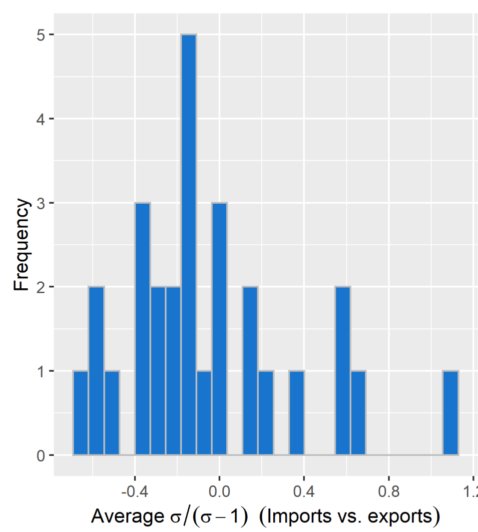
(a) Imports



(b) Exports



(c) Imports - Exports



(d) Imports - Exports (Histogram)

Notes: The top left figure plots the average CES markup $\sigma/(\sigma - 1)$ of each country's imports, weighted by trade volume, while the top right figure plots the corresponding averages for exports. The 2 bottom figures plot the difference between the two. The shaded areas reflect linear fitted lines along with their 95% confidence bands.

Interestingly however, the difference in markups between a country's imports and exports does not vary noticeably with income and we find a considerable degree of dispersion in this difference across countries. Exports of Canada, Belgium, and Vietnam for example are significantly higher-markup goods than their imports while the opposite is true for Japan, the U.K., and Germany. As shown in Figure 1c, the imports of many rich economies tend to generate higher markups than their exports do and the 5 countries with the highest difference between import and export markups are all among the richest economies in our sample. For India and Vietnam on the other hand, this gap is negative and the 3 poorest economies export goods whose markup is on average 0.2 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.

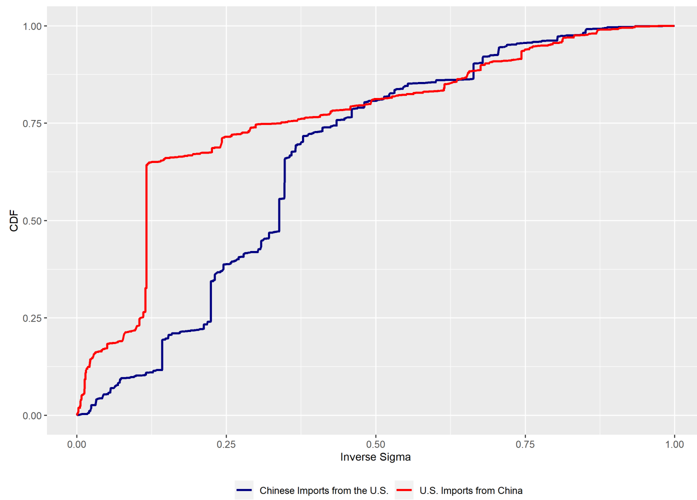
Appendix Tables F.1 and F.2 describe in more detail why our estimates differ across countries. Specifically, these tables summarize each country's 3 most important import and export sectors along with the corresponding inverse elasticities in each industry. There are several main takeaways from this table. First, countries tend to import a similar composition of goods, with e.g. machinery and vehicles being the largest import sectors in most countries. Hence, the pattern seen in Figure 1a is mainly due to 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, e.g. because of differences in income or product quality. The inverse elasticity of *Electrical Machinery and Equipment* is e.g. markedly higher in the UK than in Vietnam or Peru.

The export mix on the other hand is significantly more dispersed across countries, and especially developing as well as resource-rich countries (e.g. Bangladesh, Norway, Brazil, or Australia) tend to export noticeably different goods than they import. Belgium and Denmark for example export on average relatively high-markup goods, which is partially due to a high export share of the low-σ sector *Pharmaceutical Products*. The same is true for India, who has a high export share in *Precious Stones and Pearls*. On the other hand, a greater importance of clothing and footwear is the reason why the average export markup is comparably low in Bangladesh and Vietnam.

Importantly however, we also find a substantial degree of within-sector heterogeneity in markups, i.e. the estimated σ differs for a country's exports compared to its imports. The 3 most important import and export sectors in Austria and Germany are for example identical, but we find that the average import markup is higher than the average export one in nearly

and Warzynski (2012): The Compnet database for example reports markups for a range of European countries with the median markup equaling 1.27 at the 25th percentile and 1.99 at the 75th percentile of countries. In the case of CES preferences, these markups would imply values for σ of 4.70 and 2.01, respectively, which is in line with our estimates.

Figure 2: Cumulative Distribution Function - U.S. versus Chinese Exports



Notes: The figure plots the empirical CDF of inverse σ for goods imported by the U.S. from China as well as those which it exports to China. Each observation is weighted by trade volume $\times$ tariff.

each case. The opposite is true in Vietnam or Belgium, for which sectoral import markups are lower than the estimated export markups. The importance of within-sector heterogeneity can also be seen in more detail in Tables F.3 and F.4 as well as Tables F.5 and F.6. Specifically, the latter 2 tables report inverse demand elasticites for imports and exports if we use U.S.-based demand elasticities for all countries. Comparing Tables F.3 and F.5 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. On the other hand, China's export markups would be much smaller compared to import ones, if we used common elasticities for all countries.

Lastly, as implied by Figure 2, we also find a considerable degree of variation in the extent to which tariffs were imposed on higher versus lower markup goods in the 2018-19 U.S.-China trade war. Specifically, this figure shows the empirical CDF of the 2 countries' inverse demand elasticities across sectors, weighted by trade volume $\times$ tariff. As evident from the 2 curves, presumably to support struggling industries, U.S. tariffs were predominantly placed on lower-markup sectors compared to those affected by China's tariffs, which on average taxed higher-markup U.S. exports. It is therefore plausible, that these tariffs had an asymmetric impact on the distribution of profits across both countries and we study in detail below how this asymmetry matters for welfare.

In light of the cross-country variation documented in Figures 1 and 2, a natural question is how the observed specialization of economies into higher versus lower-markup goods translates into welfare and the gains from trade. In this paper 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 A 2×2 Model

We first illustrate the main idea and mechanisms that we quantify in this paper in a simple setting with 2 countries and 2 sectors. Section 4 then develops the quantitative model.

3.1 Framework

There are two countries in the world, Home and Foreign, and 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 country, and preferences are represented by a Cobb-Douglas function over these two sectors:

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

$$U^* = {Q_L^*}^{\alpha_L^*} {Q_H^*}^{\alpha_H^*} \quad ; \alpha_L^* + \alpha_H^* = 1 \tag{2}$$

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

$$Q_i = (\int_0^1 q(\nu)^{\frac{\sigma_i - 1}{\sigma_i}} d\nu)^{\frac{\sigma_i}{\sigma_i - 1}} \quad ; i = L, H \tag{3}$$

$$Q_i^* = (\int_0^1 q^*(\nu)^{\frac{\sigma_i - 1}{\sigma_i}} d\nu)^{\frac{\sigma_i}{\sigma_i - 1}} \quad ; i = L, H \tag{4}$$

and each variety ν is sourced from the lowest-price supplier across the world. We assume $\sigma_H < \sigma_L$.

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 Home 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 $A_H^* > 1$.

The Home and Foreign producers of variety ν compete over prices, and the one with lower marginal cost will sell the good. We assume that producers need to pay (at least part of) 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. Since the production cost has to be paid upfront, the producer which can deliver the variety ν with the lowest cost charges the optimal Dixit-Stiglitz markup $\frac{\sigma_i}{\sigma_i-1}$ over its marginal cost. Note that even though the price that the lowest-cost producer charges may be larger than the other producer's marginal cost, the other producer does not have an incentive to pay the production cost and enter this market, because she would be priced out of the market: the lowest-cost producer would charge a price below her marginal cost to take over the market, and in this case the other producer would earn negative profit because she have already paid the production cost.[4] In this pricing game, the unique equilibrium is the one in which the lowest-cost producer charges the optimal Dixit-Stiglitz markup $\frac{\sigma_i}{\sigma_i-1}$, and the other producer stays out of the market.[5]

3.2 Closed Economy

We first assume that both countries are in autarky and solve for both countries' welfare. We normalize wages in both countries to one. In autarky, total profits earned by Home producers in sector i have to equal total revenue minus total cost:

$$\Pi_i = \frac{\sigma_i}{\sigma_i - 1}\frac{Q_i}{A_i} - \frac{Q_i}{A_i} = \frac{1}{\sigma_i - 1}\frac{Q_i}{A_i} = \frac{1}{\sigma_i}\alpha_i I \tag{5}$$

where I denotes total Home income and the last equality above uses the fact that the Cobb-Douglas preference structure given by (1) implies that total expenditure on sector i is the fraction α_i of income. Further, total income I is the sum of wage income plus total profit:

$$I = L + \frac{\alpha_L I}{\sigma_L} + \frac{\alpha_H I}{\sigma_H} \Rightarrow I = \frac{L}{1 - (\frac{\alpha_L}{\sigma_L} + \frac{\alpha_H}{\sigma_H})} \tag{6}$$

Lastly, since all Home producers in sector i charge the same price $\frac{\sigma_i}{\sigma_i-1}$, the price index that the representative Home consumer faces is

$$P = (\frac{\sigma_L}{\sigma_L - 1})^{\alpha_L}(\frac{\sigma_H}{\sigma_H - 1})^{\alpha_H} \tag{7}$$

[4]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.

[5]In the pricing game in Bernard et al. (2003) and Barro and Tenreyro (2006), the price that the best producer charges is also bounded by the marginal cost of the second-best producer. Our formulation, however, substantially facilitates the quantitative analysis in the next section.

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

$$U_{aut} = \frac{I}{P} = \frac{\frac{L}{1-(\frac{\alpha_L}{\sigma_L}+\frac{\alpha_H}{\sigma_H})}}{(\frac{\sigma_L}{\sigma_L-1})^{\alpha_L}(\frac{\sigma_H}{\sigma_H-1})^{\alpha_H}} \tag{8}$$

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

$$U^*_{aut} = \frac{\frac{L}{1-(\frac{\alpha^*_L}{\sigma_L}+\frac{\alpha^*_H}{\sigma_H})}}{(\frac{\sigma_L}{\sigma_L-1})^{\alpha^*_L}(\frac{\sigma_H}{(\sigma_H-1)A^*_H})^{\alpha^*_H}} \tag{9}$$

3.3 Free Trade

We assume that international trade is frictionless and balanced, and choose the wage in Home country 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), where w^* is the equilibrium wage in Foreign economy. In this equilibrium, Home country produces all varieties of sector L only, and Foreign country produces all varieties in sector H only. Income in each country equals wage bill plus total profits from serving both markets:

$$I = L + \frac{\alpha_L I}{\sigma_L} + \frac{\alpha^*_L I^*}{\sigma_L} \quad \text{and} \quad I^* = w^* L + \frac{\alpha_H I}{\sigma_H} + \frac{\alpha^*_H I^*}{\sigma_H} \tag{10}$$

We assume trade is balanced, i.e., imports and exports of Home country are equal, $\alpha_H I = \alpha^*_L I^*$, which can be used in income equations (10) to reveal that international trade shifts the profits of producing high-markup goods from Home to Foreign economy. This in turn raises income in Foreign country in the expense of Home country's income. We call this the *profit-shifting channel* in what follows. Combining trade balance and income equations yields:

$$I = \frac{\sigma_L}{\sigma_L - 1} L \quad \text{and} \quad I^* = \frac{\sigma_H}{\sigma_H - 1} w^* L. \tag{11}$$

The income equations (11) along with trade balance can then be used to solve for the Foreign wage:

$$w^* = \frac{\alpha_H}{\alpha^*_L} \frac{\frac{\sigma_L}{\sigma_L-1}}{\frac{\sigma_H}{\sigma_H-1}} \tag{12}$$

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 (1)-(2), the price indices that the representative consumers in Home and Foreign economy face are:

$$P = (\frac{\sigma_L}{\sigma_L - 1})^{\alpha_L}(\frac{\sigma_H}{\sigma_H - 1}\frac{w^*}{A_H^*})^{\alpha_H} \quad \text{and} \quad P^* = (\frac{\sigma_L}{\sigma_L - 1})^{\alpha_L^*}(\frac{\sigma_H}{\sigma_H - 1}\frac{w^*}{A_H^*})^{\alpha_H^*} \tag{13}$$

Comparing the price indices under free trade to those in autarky shows that international trade through specialization reduces price indices, which makes both countries better off. We call this the *price channel* in what follows. We can then use the income equations (11) and price indices (13) to derive welfare in both countries:

$$U_{trade} = \frac{\frac{\sigma_L}{\sigma_L-1}L}{(\frac{\sigma_L}{\sigma_L-1})^{\alpha_L}(\frac{\sigma_H}{\sigma_H-1}\frac{w^*}{A_H^*})^{\alpha_H}} \quad \text{and} \quad U_{trade}^* = \frac{\frac{\sigma_H}{\sigma_H-1}w^*L}{(\frac{\sigma_L}{\sigma_L-1})^{\alpha_L^*}(\frac{\sigma_H}{\sigma_H-1}\frac{w^*}{A_H^*})^{\alpha_H^*}} \tag{14}$$

3.4 The Gains from Trade Openness

Given the welfare expressions (8)-(9) in autarky and (14) under free trade, we can derive the gains from trade openness for both economies:

$$\frac{U_{trade}}{U_{aut}} = \underbrace{\frac{\sigma_L}{\sigma_L - 1}(1 - (\frac{\alpha_L}{\sigma_L} + \frac{\alpha_H}{\sigma_H}))}_{\text{profit-shifting channel}} \times \underbrace{(\frac{A_H^*}{w^*})^{\alpha_H}}_{\text{price channel}} \tag{15}$$

$$\frac{U_{trade}^*}{U_{aut}^*} = \underbrace{\frac{\sigma_H}{\sigma_H - 1}(1 - (\frac{\alpha_L^*}{\sigma_L} + \frac{\alpha_H^*}{\sigma_H}))}_{\text{profit-shifting channel}} \times \underbrace{w^{*\ 1-\alpha_H^*}}_{\text{price channel}} \tag{16}$$

where the equilibrium wage w^* is given in Equation (12). To analyze the welfare consequences of trade, note that there are two potentially competing forces influencing the gains from openness in Equations (15) and (16): the price channel and profit-shifting channel. The price channel tends to raise welfare in both countries since countries gain access to cheaper varieties.[6] The profit-shifting channel, however, shifts profits of producing high-markup varieties toward the country that has comparative advantage in producing high-markup products (Foreign country here). This channel, therefore, raises welfare in the Foreign economy in the expense of the Home economy. Since these channels work in the opposite direction for the country that specializes in producing low-markup goods, such a country *may* lose from openness; The other country, however, always gains from trade. The next proposition summarizes this result.

Proposition. The profit-shifting channel tends to reduce (raise) welfare in the country

[6] As noted above, in the equilibrium $1 < w^* < A_H^*$.

that specializes in producing low- (high-) markup products. Therefore, while the country that specializes in producing high-markup goods always gains from trade, the county that specializes in low-markup products gains from trade if and only if partner's productivity is large enough.

Proof. See Appendix A.

To elaborate on the intuition behind this proposition, note that Home country may lose from openness if the price channel is not strong enough to offset the profit-shifting channel. The size of the price channel depends on the ratio $\frac{A_H^*}{w^*}$. As evident from Equation (15), if Foreign productivity A_H^* is not large enough (i.e., A_H^* is only slightly above the Foreign wage w^*),[7] Home country does not gain much from lower prices, and therefore, the profit-shifting channel would make Home country worse off. Notice that if $\sigma_L = \sigma_H$, the profit-shifting channel would not exist since the markup in both sectors would be the same. In this case, the first term in both Equations (15) and (16) would be equal to one, and therefore, both countries would definitely gain from trade due to the price channel. The result in this proposition is a special case of the general theory of the second best (Lipsey and Lancaster, 1956), i.e., in the presence of more than one friction in the economy, removing one friction might be welfare reducing. Furthermore, the conclusion is also in line with the strategic trade policy and profit shifting literature (Spencer and Brander, 1983; Brander and Spencer, 1985; Brander, 1986; Krugman, 1987; Bagwell and Staiger, 2012; Ossa, 2014).

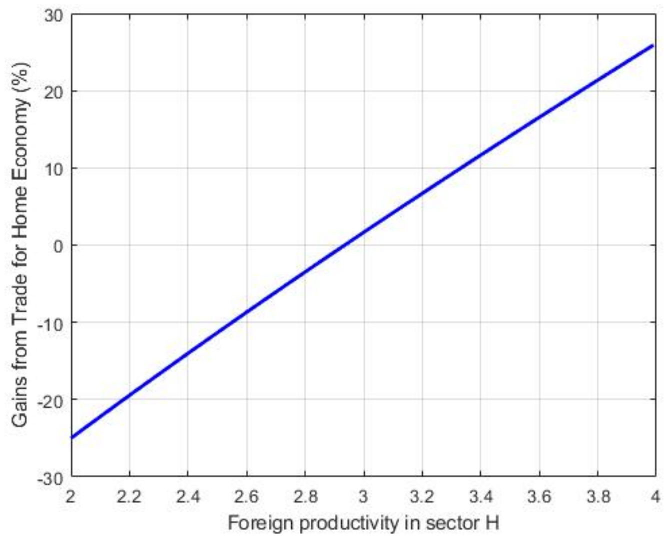
We perform a numerical exercise to show how this simple model works. To do so, we first parameterize the model and set the Cobb-Douglas parameters equal to $\alpha_H = \alpha_H^* = 0.75$ and $\alpha_L = \alpha_L^* = 0.25$. Importantly, we also assume that sector H has a lower elasticity of substitution, and 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 Home country specializes in the lower-markup sector L.

As discussed above, since the price and profit-shifting channels work in the same direction, Foreign country always gains from trade, regardless of its productivity A_H^*. More interestingly, however, Figure 3 plots the gains from trade for the Home economy as a function of $A_H^* > w^*$. We see that Home country may gain or lose from trade depending on the magnitude of A_H^*; If and only if productivity A_H^* is "large enough," the welfare gains from the price channel dominates the losses from the profit-shifting channel, and the Home economy would gain from trade.

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

[7] Note that as Equation (12) shows, the Foreign wage w^* does not vary by A_H^*.

Figure 3: Gains from Trade Openness for the Home Economy



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

specialize in low- or high-markup products. Which effect dominates and whether or not profit shifting is quantitatively important are therefore largely empirical questions which we explore using the quantitative model we develop in the next section.

4 The Quantitative Model

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

4.1 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.

4.2 Preferences and Demand Schedules

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

$$U_n = \Pi_{k=1}^{K} Q_n^k{}^{\alpha_n^k}, \qquad \sum_{k=1}^{K} \alpha_n^k = 1 \quad \forall n \in \{1, ..., N\} \tag{17}$$

where Q_n^k denotes a composite good in sector k and α_n^k is its expenditure share in country n. The composite good Q_n^k is a CES aggregate over its sub-sectors:

$$Q_n^k = [\sum_{j=1}^{J(k)} q_n^{j(k)}{}^{\frac{\sigma_n^k - 1}{\sigma_n^k}}]^{\frac{\sigma_n^k}{\sigma_n^k - 1}} \tag{18}$$

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 (18) implies the following demand for the composite good $q_n^{j(k)}$:

$$q_n^{j(k)} = \left(\frac{P_n^{j(k)}}{\mathcal{P}_n^k} \right)^{-\sigma_n^k} Q_n^k \tag{19}$$

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:

$$\mathcal{P}_n^k = [\sum_{j=1}^{J(k)} P_n^{j(k)}{}^{1-\sigma_n^k}]^{\frac{1}{1-\sigma_n^k}} \tag{20}$$

Moreover, given the preference structure (17), consumers in country n face the following price index:

$$\mathcal{P}_n = \Pi_{k=1}^{K} (\frac{\mathcal{P}_n^k}{\alpha_n^k})^{\alpha_n^k} \tag{21}$$

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

$$q_n^{j(k)} = [\int_0^1 r_n^{j(k)}(\omega)^{\frac{\sigma_n^{j(k)} - 1}{\sigma_n^{j(k)}}} d\omega]^{\frac{\sigma_n^{j(k)}}{\sigma_n^{j(k)} - 1}}, \tag{22}$$

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 (22) implies the following demand function for variety ω of sub-sector $j(k)$ in country n:

$$r_n^{j(k)}(\omega) = \left(\frac{p_n^{j(k)}(\omega)}{P_n^{j(k)}} \right)^{-\sigma_n^{j(k)}} q_n^{j(k)} \tag{23}$$

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

$$P_n^{j(k)} = \left[\int_0^1 p_n^{j(k)}(\omega)^{1-\sigma_n^{j(k)}} d\omega \right]^{\frac{1}{1-\sigma_n^{j(k)}}}. \tag{24}$$

4.3 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

$$\tau_{in}^{j(k)} = d_{in}^{j(k)}(1 + t_{in}^{j(k)}) \tag{25}$$

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.[8]

4.4 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 sole factor of production:

$$q_n^{j(k)}(\omega) = z_n^{j(k)}(\omega) l_n^{j(k)}(\omega) \tag{26}$$

[8] 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).

where $z_n^{j(k)}(\omega)$ denotes a producer's productivity, and the technology of production is assumed to be proprietary.[9] 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-price producer across the world. As in Section 3, we assume producers need to pay (at least part of) the production cost upfront and have access to a frictionless perfectly competitive financial market with zero net interest rate. Hence, as discussed in Section 3, the lowest-cost producer charges the optimal Dixit-Stiglitz markup $\frac{\sigma_n^{j(k)}}{\sigma_n^{j(k)}-1}$ over its marginal cost, and the other producers stay out of the market. Hence, the price of a variety ω in sub-sector $j(k)$ in country n is

$$p_n^{j(k)}(\omega) = (\frac{\sigma_n^{j(k)}}{\sigma_n^{j(k)} - 1}) \times \min_i\{\frac{w_i \tau_{in}^{j(k)}}{z_i^{j(k)}(\omega)}\} \tag{27}$$

where w_i denotes the wage in country i.

4.5 Trade Shares and Total Income

As Appendix B shows, we can use the price equation (27) along with the properties of Fréchet distribution to derive the price index $P_n^{j(k)}$ in (24) as

$$P_n^{j(k)} = A_n^{j(k)}[\sum_{i=1}^{N} T_i^{j(k)}(w_i \tau_{in}^{j(k)})^{-\theta^{j(k)}}]^{\frac{-1}{\theta^{j(k)}}}, \tag{28}$$

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[10]

$$\frac{X_{in}^{j(k)}}{X_n^{j(k)}} \equiv \pi_{in}^{j(k)} = \frac{T_i^{j(k)}(w_i \tau_{in}^{j(k)})^{-\theta^{j(k)}}}{\sum_{h=1}^{N} T_h^{j(k)}(w_h \tau_{hn}^{j(k)})^{-\theta^{j(k)}}} \tag{29}$$

[9] 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 away 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.

[10] See Appendix B for more details.

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 (17), consumers in n spend a fraction α_n^k of their income on goods produced in sector k. Together with Equation (19), this implies that

$$X_n^{j(k)} = \alpha_n^k I_n \left(\frac{P_n^{j(k)}}{\mathcal{P}_n^k}\right)^{1-\sigma_n^k}. \tag{30}$$

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:

$$I_n = w_n L_n + Y_n + R_n + D_n, \tag{31}$$

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 equals $\frac{1}{1+t_{ni}^{j(k)}} \pi_{ni}^{j(k)} X_i^{j(k)}$. 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

$$Y_n = \sum_{k=1}^{K} \sum_{j=1}^{J(k)} \sum_{i=1}^{N} \frac{\pi_{ni}^{j(k)} X_i^{j(k)}}{\sigma_i^{j(k)}(1+t_{ni}^{j(k)})}. \tag{32}$$

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

$$R_n = \sum_{k=1}^{K} \sum_{j=1}^{J(k)} \sum_{i=1}^{N} \frac{t_{in}^{j(k)}}{(1+t_{in}^{j(k)})} \pi_{in}^{j(k)} X_n^{j(k)} \tag{33}$$

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):

$$\sum_{k=1}^{K} \sum_{j=1}^{J(k)} \sum_{i=1}^{N} \frac{\pi_{in}^{j(k)} X_n^{j(k)}}{(1+t_{in}^{j(k)})} - D_n = \sum_{k=1}^{K} \sum_{j=1}^{J(k)} \sum_{i=1}^{N} \frac{\pi_{ni}^{j(k)} X_i^{j(k)}}{(1+t_{ni}^{j(k)})} \tag{34}$$

It can then be shown that trade balance (34) implies labor market clearing. Specifically, summing over all sub-sectors $j(k)$ and all sectors k in Equation (30), and using the trade balance allows one to write:

$$w_nL_n = \sum_{k=1}^{K}\sum_{j=1}^{J(k)}\sum_{i=1}^{N}\frac{\pi_{ni}^{j(k)}X_i^{j(k)}}{(1+t_{ni}^{j(k)})} - Y_n = \sum_{k=1}^{K}\sum_{j=1}^{J(k)}\sum_{i=1}^{N}\frac{(\sigma_i^{j(k)}-1)\pi_{ni}^{j(k)}X_i^{j(k)}}{\sigma_i^{j(k)}(1+t_{ni}^{j(k)})} \tag{35}$$

4.6 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 (20), (28), (29), (30), (31), (32), (33), and (34).

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 (28) under τ' by the one under τ, and then use (29) to remove $T_n^{j(k)}$:

$$\hat{P}_n^{j(k)} = \left[\sum_{i=1}^{N}\pi_{in}^{j(k)}(\hat{w}_i\hat{\tau}_{in}^{j(k)})^{-\theta^{j(k)}}\right]^{\frac{-1}{\theta^{j(k)}}} \tag{36}$$

Then, the expressions for the price index (28) and for trade shares (29) can be combined to write the latter in relative terms:

$$\hat{\pi}_{in}^{j(k)} = \left[\frac{\hat{w}_i\hat{\tau}_{in}^{j(k)}}{\hat{P}_n^{j(k)}}\right]^{-\theta^{j(k)}} \tag{37}$$

Next, we write total expenditure (30) in relative terms

$$\hat{X}_n^{j(k)} = \hat{I}_n(\frac{\hat{P}_n^{j(k)}}{\hat{\mathcal{P}}_n^k})^{1-\sigma_n^k} \tag{38}$$

and use Equation (30) to write

$$\hat{\mathcal{P}}_n^{k\ 1-\sigma_n^k} = \frac{\mathcal{P'}_n^{k\ 1-\sigma_n^k}}{\mathcal{P}_n^{k\ 1-\sigma_n^k}} = \frac{\sum_{j=1}^{J(k)}P_n^{\prime j(k)\ 1-\sigma_n^k}}{\mathcal{P}_n^{k\ 1-\sigma_n^k}} = \frac{1}{\alpha_n^kI_n}\sum_{l=1}^{J(k)}\hat{P}_n^{l(k)\ 1-\sigma_n^k}X_n^{l(k)} \tag{39}$$

Substituting the latter into former delivers[11]

$$X_n^{\prime j(k)} = \alpha_n^k I'_n \frac{\hat{P}_n^{j(k)\ 1-\sigma_n^k} X_n^{j(k)}}{\sum_{l=1}^{J(k)} \hat{P}_n^{l(k)\ 1-\sigma_n^k} X_n^{l(k)}} \tag{40}$$

Using the income equation (31), we can then write income under counterfactual trade frictions as follows:

$$I'_n = \hat{w}_n w_n L_n + Y'_n + R'_n + D_n \tag{41}$$

where

$$Y'_n = \sum_{k=1}^{K} \sum_{j=1}^{J(k)} \sum_{i=1}^{N} \frac{\pi_{ni}^{\prime j(k)} X_i^{\prime j(k)}}{\sigma_i^{j(k)}(1 + t_{ni}^{\prime j(k)})} \tag{42}$$

$$R'_n = \sum_{k=1}^{K} \sum_{j=1}^{J(k)} \sum_{i=1}^{N} \frac{t_{in}^{\prime j(k)}}{(1 + t_{in}^{\prime j(k)})} \pi_{in}^{\prime j(k)} X_n^{\prime j(k)} \tag{43}$$

and we assume that trade deficits remain unchanged. Similarly, the trade balance equation (34) can be used to derive the trade balance under counterfactual trade frictions as

$$\sum_{k=1}^{K} \sum_{j=1}^{J(k)} \sum_{i=1}^{N} \frac{\pi_{in}^{\prime j(k)} X_n^{\prime j(k)}}{(1 + t_{in}^{\prime j(k)})} - D_n = \sum_{k=1}^{K} \sum_{j=1}^{J(k)} \sum_{i=1}^{N} \frac{\pi_{ni}^{\prime j(k)} X_i^{\prime j(k)}}{(1 + t_{ni}^{\prime j(k)})} \tag{44}$$

Equilibrium Definition in Relative Terms Given Frećhet shape parameters $\theta^{j(k)}$, elasticities of substitution σ_n^k and $\sigma_n^{j(k)}$, Cobb-Douglas shares α_n^k, total expenditures $X_n^{j(k)}$, trade shares $\pi_{in}^{j(k)}$, labor endowments L_n, relative trade frictions $\hat{\tau}_{in}^{j(k)}$, and ad valorem tariffs $t_{in}^{\prime j(k)}$, an equilibrium is characterized by a set of relative wages $\{\hat{w}_n\}_{n=1}^N$ that satisfy equilibrium conditions (36), (37), (40), (41), (42), (43), and (44).

[11]The model presented in the main text does not feature intermediate inputs and input-output linkages. However, our model in principle 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 (30)

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

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.

4.7 Extension: Incorporating Multinationals into the Model

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

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

$$Y_n = \sum_{k=1}^{K}\sum_{j=1}^{J(k)}\sum_{i=1}^{N}(1-\gamma_n^{j(k)})\frac{\pi_{ni}^{j(k)}X_i^{j(k)}}{\sigma_i^{j(k)}(1+t_{ni}^{j(k)})} + \sum_{k=1}^{K}\sum_{j=1}^{J(k)}\sum_{i=1}^{N}\sum_{m\neq n}\gamma_m^{j(k)}\lambda_{nm}^{j(k)}\frac{\pi_{mi}^{j(k)}X_i^{j(k)}}{\sigma_i^{j(k)}(1+t_{mi}^{j(k)})} \tag{45}$$

where the first term is country n's profits earned from production in country n, and the second term is the profits earned in other countries from owning shares of multinational companies.

We also solve this model in relative terms using the exact hat algebra. All the equilibrium conditions stated before hold in this model except for the counterfactual profits and trade balance. For counterfactual profits we can write:

$$Y'_n = \sum_{k=1}^{K}\sum_{j=1}^{J(k)}\sum_{i=1}^{N}(1-\gamma_n^{j(k)})\frac{\pi_{ni}^{\prime j(k)}X_i^{\prime j(k)}}{\sigma_i^{j(k)}(1+t_{ni}^{\prime j(k)})} + \sum_{k=1}^{K}\sum_{j=1}^{J(k)}\sum_{i=1}^{N}\sum_{m\neq n}\gamma_m^{j(k)}\lambda_{nm}^{j(k)}\frac{\pi_{mi}^{\prime j(k)}X_i^{\prime j(k)}}{\sigma_i^{j(k)}(1+t_{mi}^{\prime j(k)})} \tag{46}$$

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

In the model with multinationals, the labor market clearing condition looks simpler than the trade balance, and therefore we will work with the former. The labor market clearing condition looks exactly like equation (35), which in relative terms can be written as

$$\hat{w}_n w_n L_n = \sum_{k=1}^{K} \sum_{j=1}^{J(k)} \sum_{i=1}^{N} \frac{(\sigma_i^{j(k)} - 1)\pi_{ni}^{\prime j(k)} X_i^{\prime j(k)}}{\sigma_i^{j(k)}(1 + t_{ni}^{\prime j(k)})} \tag{47}$$

4.8 Solving for the Equilibrium

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

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

ii) Compute $\hat{P}_n^{j(k)}$ using equation (36).

iii) Use equation (37) to compute $\hat{\pi}_{in}^{j(k)}$.

iv) Use the system of equations (40)-(43) (or using equation (46) instead of (42) in the extension featuring multinationals) to solve for counterfactual expenditures $X_n^{\prime j(k)}$.[12]

v) Update $\hat{w}_n$ until the trade balance equation (44) (or equation (47) in the extension featuring multinationals) is satisfied.

4.9 Welfare

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

$$W_n = \frac{I_n}{\mathcal{P}_n}. \tag{48}$$

Using the definition of total income I_n in equation (31), 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:

$$\hat{W}_n - 1 = \left(\frac{\hat{w}_n}{\hat{\mathcal{P}}_n} - 1\right)\frac{w_n L_n}{I_n} + \left(\frac{\hat{Y}_n}{\hat{\mathcal{P}}_n} - 1\right)\frac{Y_n}{I_n} + \left(\frac{\hat{R}_n}{\hat{\mathcal{P}}_n} - 1\right)\frac{R_n}{I_n} + \left(\frac{1}{\hat{\mathcal{P}}_n} - 1\right)\frac{D_n}{I_n} \tag{49}$$

[12]This is a system of 36,000+ equations and unknowns, since we have 30 countries and 1200+ subsectors $j(k)$ (see Section 5 below). Due to the problem's dimensions, solving for equilibrium takes about 2 hours on a 40-core machine.

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.[13] We explore this decomposition in detail in our counterfactual experiments.

5 Data, Estimation, and Cross-Validation

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.[14] 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.[15] To map the model to the data, we treat sectors k and sub-sectors $j(k)$ as 2-digit and 4-digit HS codes, respectively.

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.[16] Overall, our final dataset contains 4,111 distinct HS6 product categories.

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

[14]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.

[15]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, which is broader than the HS4 classification, we crosswalk it to the HS4 level and assume that the domestic share in each HS4 category is equal to that of the corresponding GTAP sector.

[16]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.

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 HS4 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. We also infer each country's wage bill by using information on labor income shares as a percentage of GDP as provided by the ILO.

Finally, we use several data sources to compute the share of each country in the profits generated in each sector in foreign countries. To infer the total share of multinationals from profits generated in each sector-country pair, $\gamma_n^{j(k)}$, we use OECD data on *inward activity of multinationals by industrial sector*. For each country and each of the 2-digit ISIC revision 4 sectors, these data report gross operating surplus by multinationals as well as national totals. Therefore we can identify the total share of multinationals in gross operating profits in each 2-digit ISIC sector-country, and we assume that all HS4 sectors belonging to a 2-digit ISIC sector have the same share.[17] For countries that do not exist in the OECD data, we use UNCTAD and WDI data to construct total inflow FDI stock divided by total capital stock to infer the share of multinationals in that country. Since this data is not sector-specific, for these countries we assume all sectors have the same share of multinationals.

Lastly, to infer the share of each country in total multinational activities in other countries, $\lambda_{in}^{j(k)}$, we use OECD data on *Inward activity of multinationals by investing country*. These data report gross operating surplus in the manufacturing sector by an investor country in a recipient country. Since the detailed information for each sector is not available, we assume these shares are the same across all sectors. Moreover, for the countries not included in the OECD dataset, we use UNCTAD data on inward FDI stock for an investor country in a recipient country. Table 1 provides detailed summary statistics of the final dataset.

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 (29), we follow Caliendo and Parro (2015) to show that trade elasticities $\theta^{j(k)}$ can be, under relatively mild assumptions,

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

Table 1: Summary Statistics

	Mean	Std. Deviation	N
Imports (in bn. $)	0.14	19.87	1,101,600
Exp. Share	0.03	0.13	1,101,600
Wage Bill (in tr. $)	2.09	3.53	1,101,600
Tariff (MFN, ad valorem)	3.70	17.91	1,101,600
Tariff (applied, ad valorem)	2.29	15.93	1,101,600
Tariff - Trade War (U.S., ad valorem)	18.72	8.79	1,230
Tariff - Trade War (China, ad valorem)	18.45	10.12	1,230
Share of Multinationals in Sector-Country, $\gamma_n^{j(k)}$	0.22	0.11	36,720
Share of Investor in Recipient Country, λ_{in}	0.03	0.07	870
Profit Margin (ORBIS data)	1.41	0.38	303,331
Markup (ORBIS data)	1.77	1.14	290,217
Labor Share (ORBIS data)	0.50	0.22	303,303

	Median	Std. Deviation	N
θ	2.12	1.99	1,101,600
θ (CEPII)	8.09	9.68	1,101,600
σ	2.60	1,357.76	1,101,600

estimated via equation

$$\ln\left(\frac{X_{ni}^{j(k)} X_{ih}^{j(k)} X_{hn}^{j(k)}}{X_{in}^{j(k)} X_{hi}^{j(k)} X_{nh}^{j(k)}}\right) = -\theta^{j(k)} \ln\left(\frac{\tilde{t}_{ni}^{j(k)} \tilde{t}_{ih}^{j(k)} \tilde{t}_{hn}^{j(k)}}{\tilde{t}_{in}^{j(k)} \tilde{t}_{hi}^{j(k)} \tilde{t}_{nh}^{j(k)}}\right) + \tilde{\epsilon}_{ihn}^{j(k)}, \tag{50}$$

using OLS, where $\tilde{t}_{ni}^{j(k)} = 1 + t_{ni}^{j(k)}$.[18] 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 (50) and also in the counterfactuals, we assume that all 4-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.[19] 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. 8703), buses (e.g. 8702), and trucks (e.g. 8704).

[18] 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.

[19] We make this assumption because estimating trade elasticities separately for each 4-digit HS sector results in quite a few negative $\theta^{j(k)}$, which are inconsistent with theory.

Our assumption hence implies that θ is equal to 0.13 for each of these 4-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 1.95 across sectors, which is in line with Caliendo and Parro (2015) who find elasticities which range between 0.37 and 51.08 across sectors. 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 30% of sectors. In those cases, we instead use the median $\theta^{j(k)}$ for those sectors in the counterfactuals.

As an alternative, to assess the robustness of our findings, we also quantify a version of our model in which we instead rely on recent estimates of HS4-level trade elasticities by Fontagné, Guimbard and Orefice (2019). Table 2 summarizes these estimates, called θ (CEPII). This robustness exercise has 2 benefits: First, only a small fraction of these estimates is negative, which alleviates concerns that our results are partially driven by replacing a subset of $\theta^{j(k)}$ with the median estimate. In addition, Fontagné, Guimbard and Orefice (2019)'s estimates are generally larger and this specification hence also assesses how sensitive the counterfactual welfare changes are to trade flows being more or less sensitive to changes in trade costs.

5.3 Estimation of the Elasticities of Substitution

We estimate the elasticity of substitution at both the HS4 and HS2 level, separately for each country, and by using 2 different methods. Our baseline specification utilizes the hybrid estimator method (LIML) proposed in Soderbery (2015), which is based on the approach developed by Feenstra (1994), but addresses potential small sample biases as well as grid search inefficiencies present in previous applications.[20] As a second alternative, we infer $\sigma_n^{j(k)}$ based on the De Loecker and Warzynski (2012) markups that we estimate using the ORBIS database,

[20]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. In practice, however, in line with recent findings by Fajgelbaum et al. (2020), our estimates of the inverse export supply elasticity tend to be very small in most sectors: For exporters to the U.S., for example, we estimate a median inverse elasticity of 0.043. Further, less than one third of export supply elasticities are statistically different from zero, which is consistent with supply being horizontal in the majority of sectors and which suggests that our estimates of $\sigma_n^{j(k)}$ would likely be similar if we imposed a horizontal export supply curve in the estimation as well.

Table 2: Distribution of parameter estimates for θ and σ

	Median	1st Quartile	3rd Quartile
θ	1.95	-1.26	3.96
θ (CEPII)	8.09	5.66	12.47

σ	Median	1st Quartile	3rd Quartile	Share statistically significant	Share statistically different from U.S. σ
Australia	2.06	1.35	4.74	89.68	58.22
Austria	3.09	1.60	7.24	87.41	67.74
Bangladesh	2.90	1.54	7.67	92.85	79.16
Belgium	3.01	1.76	8.21	92.10	66.67
Brazil	2.59	1.59	5.37	87.11	65.06
Canada	4.74	2.01	15.10	94.00	68.31
China	2.76	1.71	5.68	89.58	64.04
Denmark	2.28	1.53	5.92	94.33	74.24
France	2.80	1.62	6.55	86.87	66.03
Germany	2.23	1.39	5.05	91.77	71.57
Greece	2.28	1.51	4.37	82.97	54.28
India	2.64	1.61	6.29	89.85	68.00
Indonesia	2.32	1.56	4.25	91.21	65.51
Italy	2.02	1.39	3.81	89.68	58.22
Japan	1.98	1.35	4.09	88.73	71.26
Rep. of Korea	2.87	1.63	5.24	82.66	66.66
Mexico	3.22	1.78	6.67	90.25	69.99
Netherlands	2.85	1.56	6.20	87.05	60.63
New Zealand	2.88	1.61	6.73	89.80	63.74
Norway	2.31	1.61	3.53	77.93	53.65
Peru	2.65	1.63	5.46	81.04	66.03
Romania	2.38	1.54	4.85	90.78	68.00
Russia	2.43	1.60	5.15	90.79	73.03
Vietnam	6.80	2.48	16.06	77.04	73.91
Spain	2.65	1.74	4.64	84.24	62.16
Sweden	2.76	1.51	8.69	87.21	58.44
Egypt	2.15	1.50	4.43	89.79	72.00
United Kingdom	1.85	1.38	3.53	87.67	61.76
USA	2.07	1.47	6.11	89.36	-
ROW	2.67	1.42	9.06	88.74	53.12

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 4-digit sectors. The median and quartiles are taken over product categories. Standard errors for σ are computed via the delta method and we refer to an estimate as statistically significant (i.e. different from 1) whenever the corresponding t statistic exceeds 1.96. The reported fractions are similar when assessing if the estimates are significantly different from 0. Analogously, we assess whether or not the estimates for σ are statistically different from the U.S. via 2-sided t-tests.

as discussed in more detail in Section 5.4. Specifically, we use that the optimal CES markup equals $\sigma_n^{j(k)}/(\sigma_n^{j(k)}-1)$ to back out the values for $\sigma_n^{j(k)}$ which rationalize the observed markups in the data.

More concretely, in our baseline approach, we first introduce a time subscript t as well as time-variety-specific taste shocks $b_{nt}^{j(k)}(\omega)$ into the CES aggregator in equation (22), such that

$$q_{nt}^{j(k)} = \left[\int b_{nt}^{j(k)}(\omega)^{\frac{1}{\sigma_n^{j(k)}}} r_{nt}^{j(k)}(\omega)^{\frac{\sigma_n^{j(k)}-1}{\sigma_n^{j(k)}}} d\omega \right]^{\frac{\sigma_n^{j(k)}}{\sigma_n^{j(k)}-1}} \tag{51}$$

We treat each HS6-origin-destination combination that we observe in the data as one variety ω who is the winner of the competition among firms for this particular variety ω in that destination. Hence, within each 4-digit sector in a given country there is a range of HS6 varieties, each supplied by a single producer. The assumption that each HS6-source-destination combination is supplied by one producer is arguably a realistic one for many countries in our sample. For example, Hummels et al. (2014) find that for Denmark, the median number of exporters in each HS6-destination is 1 and equals 3 at the 90th percentile. Moreover, as reported in the World Bank's Exporter Dynamics Database, the median number of exporters in HS2-destination pairs for the countries that are part of our sample is: Bangladesh (2), Denmark (4), Egypt (3), Mexico (4), Norway (3), Peru (3), and Spain (10).[21] On the more disaggregated 6-digit level it is hence arguably reasonable that an HS6-source-destination combination is supplied by only one producer.

Intuitively, in our baseline approach, $\sigma_n^{j(k)}$ is hence identified from substitution across varieties, i.e. from the responsiveness of expenditure shares on a given HS6 variety to changes in ex post observed unit values. This e.g. includes cases in which households substitute a variety offered by country i with another variety offered by the same country. In contrast, the trade elasticity $\theta^{j(k)}$ is identified from changes in HS4-level market shares due to changes in trade costs and is necessarily driven by substitution from one country to another one. Consequentially, we find that the correlation between the estimates of sigma and theta is in fact quite weak, and indeed slightly negative for several countries in our sample.

In practice, we follow Soderbery (2015) and Broda and Weinstein (2006) by allowing for a potentially upward-sloping export supply curve, in which case this structure implies demand and supply curves of the form

$$\Delta^m ln(s_{nt}^{j(k)}(\omega)) = -(\sigma_n^{j(k)} - 1)\Delta^m ln(p_{nt}^{j(k)}(\omega)) - \xi_{nt}^{j(k)}(\omega) \tag{52}$$

$$\Delta^m ln(p_{nt}^{j(k)}(\omega)) = \left[\frac{\kappa_n^{j(k)}}{1 + \kappa_n^{j(k)}}\right]\Delta^m ln(s_{nt}^{j(k)}(\omega)) + \delta_{nt}^{j(k)}(\omega) \tag{53}$$

where Δ^m denotes double differencing with respect to time and a reference variety m, $\kappa_n^{j(k)}$ denotes the inverse export supply elasticity for good $j(k)$, $s_{nt}^{j(k)}$ its expenditure share, and

[21] These data are for the last three years reported by the World Bank, i.e., 2012-2014.

$\xi_{nt}^{j(k)}(\omega)$ and $\delta_{nt}^{j(k)}(\omega)$ reflect unobservable demand and supply shocks.

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

$$\left(\Delta^m ln(p_{nt}^{j(k)}(\omega))\right)^2 = \lambda_{1,j(k)}\left(\Delta^m ln(s_{nt}^{j(k)}(\omega))\right)^2 + \lambda_{2,j(k)}\left(\Delta^m ln(p_{nt}^{j(k)}(\omega))\right)\left(\Delta^m ln(s_{nt}^{j(k)}(\omega))\right) + u_{nt}^{j(k)} \quad (54)$$

where $\lambda_{1,j(k)} = \kappa_n^{j(k)}/[(\kappa_n^{j(k)}+1)\cdot(\sigma_n^{j(k)}-1)]$ and $\lambda_{2,j(k)} = [1-\kappa_n^{j(k)}(\sigma_n^{j(k)}-2)]/[(\kappa_n^{j(k)}+1)\cdot(\sigma_n^{j(k)}-1)]$, which can be consistently estimated using 2SLS estimation with variety indicators as instruments.[22]

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 4-digit 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.[23] 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, Canada, and Mexico.[24]

Table 2 also shows that most elasticities are precisely estimated with for the majority of countries more than 80% being significantly different from 1. More importantly, in the majority of cases we can also reject that elasticities are the same as those estimated for the U.S., which supports our decision to allow for country-specific import demand elasticities. Specifically, we find that across all potential country-pair-sector combinations, more then 65% of elasticities are significantly different.

Generally, we find that about 37% 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

[22]Following Soderbery (2015), we weight varieties by their respective estimated residuals to limit the impact of outliers.

[23]In estimating each HS2 elasticity, as in Broda and Weinstein (2006), we include all associated HS6-country observations.

[24]More generally, we also found the average elasticity to be noticeably larger than the median and to an even larger degree than e.g. Broda and Weinstein (2006), which is due to a small number of categories with very large estimates. In practice however, these large estimates have only a small impact on the results as the markup is effectively 0 for those products and hence contribute very little to profit shifting.

example due to varying income levels, which might explain why the median σ is comparably high in the poorer economies Vietnam, India, and China.

Furthermore, 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.

Finally, the correlation between markups and trade elasticities plays a key role in quantitative importance of profit shifting. In particular, Ossa (2014) as well as other Armington-type frameworks in trade literature impose a perfect positive correlation between trade elasticities and import demand elasticities, i.e., trade elasticities equal $\sigma - 1$. This structure implies that high-markup sectors have low trade elasticities and therefore respond less to changes in trade barriers, which in turn limits the role of profit shifting in welfare consequences of trade. In our paper, however, import demand elasticities and trade elasticities are separately estimated and are weakly correlated (if anything), with the correlation coefficient ranging from -6% to 7% across our sample countries. Alternatively, the correlation between import demand elasticities and CEPII trade elasticities tells the same story, with the correlation coefficient ranging from -4% to 7%. As we show below, imposing trade elasticities θ to be equal to $\sigma - 1$ would substantially reduce the quantitative importance of profit shifting.

5.4 Cross-Validation of Demand Elasticities

Since demand elasticities are tightly linked to profits in our model and since profits are at the heart of our analysis, we use other data sources to cross-validate our demand elasticity estimates. In particular, we show that our model-implied markups are positively correlated with profit margins as well as markups in several countries, and are negatively correlated with labor shares.

To do so, we rely on the ORBIS firm-level dataset in this section, which provides balance sheet information on both larger and smaller companies in several countries along a wide range of dimensions. We restrict our analysis to a sample of 8 European countries, for which ORBIS has particularly good coverage, in order to avoid having to rely on the smaller sample sizes for a range of other countries in the dataset.[25] These countries have good data coverage on the

[25]Specifically, we use data for the following countries: Austria, Belgium, France, Germany, Italy, Norway,

key variables that we use here, including revenue, wage bill, capital stock, and material costs. Since our trade data is for 2015, we focus on the same year in our analysis here.

To cross-validate our import demand elasticities, we use two measures: profit margin and markups. As for profit margins, we first compute firm-level revenue-cost margins defined as sales over the sum of wage bill, material costs, and capital costs for each firm.[26] We then use the average of these profit margins across all companies within 3-digit SIC codes in each country as the measure of sector-country level profit margin.[27] As for markups, we employ the De Loecker and Warzynski (2012) methodology and estimate firm-level markups. We then take the average markup within each 3-digit SIC-country pair as the sector-country level markup. Table 1 reports the summary statistics for firm-level profit margins and markups.

To map 3-digit SIC codes in ORBIS to HS4 codes in our trade data, we use the concordance developed by Pierce and Schott (2012).[28] We then use our trade data and estimated import demand elasticities to compute our model-implied trade-weighted average markups that each SIC-country pair charges across the world.[29] Encouragingly, we find that the profit margins and markups in the ORBIS data are positively correlated with our model-implied markups, with the correlation coefficient being 41% and 38%, respectively.[30] This is consistent with the idea that the elasticity of substitution is a quantitatively important determinant of profitability and markups.

Our model also generates a negative relationship between markups and labor shares, consistent with the predictions and findings in other papers in the literature, e.g., Edmond, Midrigan and Xu (2015).[31] This insight provides us with another way to cross-validate our estimates by testing whether or not sectoral labor shares in the data are indeed correlated with the predicted markups implied by our elasticity estimates. To explore this idea empirically, we compute firm-

Spain, and Sweden.

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

[27] To limit the impact of outliers, we winsorize variables at 5 and 95 percent. For all our results using ORBIS data presented here, we perform several robustness checks. First, the results are robust to winsorizing at 1 and 99 percent. Moreover, we also used cross-firm median (rather than average) and results remained almost identical. As another robustness check, we performed the analysis at 4-digit SIC codes, and the results were largely similar.

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

[29] To ensure that our results are not driven by very low demand elasticities (i.e., very large markups), we winsorize demand elasticities at the 5% level, which is equal to the demand elasticity of 1.15. The results are robust to winsorizing at other levels, or to not winsorizing.

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

[31] This is because firms' F.O.C. implies that markup is equal to labor elasticity of output (which is one in our framework) over labor share of sale. Also look at the pioneering work by Hall, Blanchard and Hubbard (1986) and De Loecker and Warzynski (2012).

level labor share in our ORBIS data as wage bill divided by sales minus material costs. Table 1 reports summary statistics for firm-level labor shares. We then take the average across all firms within the same 3-digit SIC-country pair and then compare them with the model-implied average markups at the SIC-country level constructed above. As expected, there is a negative association between labor share (in data) and average markup (in model) at the SIC-country level, with a correlation coefficient of -35%.[32]

Finally, as described above, this paper focuses on variation in markups due to cross-country differences in demand elasticities. This focus is motivated by ample evidence that these elasticities are not equal across countries and e.g. vary due to heterogeneity in income or idiosyncratic preferences for individual sectors (see e.g. Fajgelbaum and Khandelwal, 2016; Caron, Fally and Markusen, 2014; Fieler, 2011) and our counterfactual results highlight that such variation can already have immense quantitative implications for profit shifting and the welfare consequences of trade wars. We are however largely agnostic about the question of why elasticities vary across countries and solely rely on our empirical estimates to identify such heterogeneity, which e.g. restricts us from inference on inequality. While such an extension is beyond the scope of the paper, it would certainly be insightful and likely deliver meaningful results, given the sizable quantitative implications of markup asymmetry in our counterfactuals.[33]

6 Counterfactual Analysis

In this section, we use the quantitative model developed in Section 4 to study the welfare consequences of different trade policies. In particular, we quantify the welfare implications of a counterfactual global tariff war, the welfare consequences of the recent U.S.-China tariff war, and the gains from trade (i.e., gains from moving from autarky to the observed trade volumes).

To emphasize the role of the 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 4. In the second version, we slightly change the technology described in Section 4.4: In particular, we follow the standard perfect competition assumption in Ricardian models (e.g., Eaton and Kortum, 2002; 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

[32]This result is robust to defining labor share as wage bill divided by sales.

[33]A related concern is that demand elasticities may themselves be affected by tariffs, e.g. through changes in household income. This however is alleviated by the fact that our counterfactuals, especially those related to the U.S.-China trade war, predict quite moderate changes in income, especially in contrast to any existing income differences across countries. It is therefore unlikely that this channel would have a large impact on our results.

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 4.6, 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 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. We follow the approach by Dekle, Eaton and Kortum (2008), Ossa (2014), and Caliendo and Parro (2015) among others to take care of trade deficits, i.e., 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.[34]

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 with the perfect competition model. Columns "welfare" report the percentage change in welfare. Based on the welfare decomposition (49), 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.[35] 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.

[34] To ensure that outlier elasticities do not govern our counterfactual results, we also winsorized the estimated 2-digit and 4-digit elasticities of substitution from above at 20, and from below at 1.15. As a robustness check, we also perform all our exercises without winsorizing elasticities, and results remain almost identical.

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

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	-0.781	-1.283	-0.990	1.492	-0.636	-2.130	1.494
Austria	-1.163	-1.597	-1.480	1.914	-0.873	-2.792	1.919
Bangladesh	-0.090	-0.226	-0.074	0.211	-0.137	-0.348	0.211
Belgium	-3.591	-3.120	-3.934	3.463	-1.673	-5.188	3.515
Brazil	-0.330	-0.633	-0.253	0.556	-0.497	-1.052	0.555
Canada	-4.347	-3.216	-4.004	2.873	-1.568	-4.505	2.937
China	-0.236	-0.552	-0.276	0.592	-0.249	-0.841	0.592
Denmark	-2.154	-3.094	-2.461	3.401	-1.456	-4.872	3.416
France	-1.572	-1.773	-1.791	1.992	-0.749	-2.756	2.007
Germany	0.048	-1.344	-0.186	1.578	-0.545	-2.115	1.571
Greece	-0.669	-0.626	-0.739	0.696	-0.329	-1.028	0.699
India	-0.308	-0.273	-0.250	0.216	-0.160	-0.376	0.216
Indonesia	0.093	-1.024	-0.063	1.179	-0.525	-1.699	1.175
Italy	0.061	-0.860	-0.149	1.069	-0.324	-1.391	1.067
Japan	0.275	-0.242	0.184	0.333	-0.112	-0.444	0.333
Rep. of Korea	-0.314	-0.442	-0.277	0.406	-0.197	-0.603	0.406
Mexico	-0.658	-1.804	-0.756	1.901	-0.752	-2.658	1.906
Netherlands	-1.401	-1.757	-1.849	2.205	-0.892	-3.107	2.215
New Zealand	-1.408	-1.430	-1.198	1.220	-0.791	-2.018	1.227
Norway	-0.911	-1.609	-1.158	1.856	-0.806	-2.662	1.856
Peru	-0.182	-0.231	-0.210	0.259	-0.084	-0.343	0.259
Romania	-0.271	-0.727	-0.400	0.856	-0.325	-1.181	0.855
Russia	-0.822	-0.794	-0.853	0.824	-0.459	-1.286	0.826
Vietnam	-2.739	-1.927	-2.514	1.703	-1.002	-2.732	1.730
Spain	-0.328	-0.591	-0.523	0.786	-0.283	-1.069	0.786
Sweden	1.026	-0.644	0.483	1.188	-0.476	-1.653	1.177
Egypt	-0.065	-0.359	-0.068	0.363	-0.282	-0.644	0.361
United Kingdom	0.202	-1.439	-0.229	1.870	-0.799	-2.655	1.856
USA	-0.306	-0.450	-0.475	0.618	-0.251	-0.869	0.618
ROW	-0.919	-2.208	-1.346	2.635	-1.056	-3.681	2.625

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 (49), 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.

As shown in Figure 4, 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 4a and 4b, predicted welfare changes are significantly larger in magnitude when we account for profit shifting and range from 1.0 to -4.4 percent compared to only up to -1.7% 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.[36] Countries such as Vietnam, Canada, and Belgium for example experience welfare declines between 2.7% and 4.4% while Germany, the U.K., or 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.

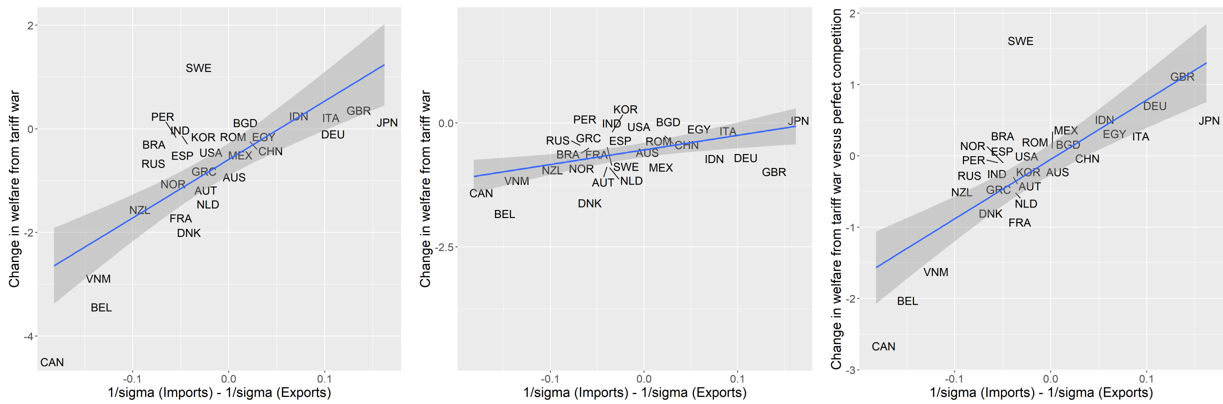
As evident from Table 3, the main reason for this finding is that profits decline much more strongly in other countries, with the consequence that the additional tariff revenue compensates for declines in wages and profits in those 3 countries. For most countries, the changes in wages and tariff revenue 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 4c 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, and these measures are strongly correlated with a coefficient of 0.77. As Figure 4c 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 in the baseline model is larger than the welfare loss in the perfect competition setting by almost 3 percentage points for Canada, 2 percentage points for Belgium, or 1.7 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 1 percentage point smaller for the U.K., and 0.6 percentage points for Germany and Indonesia. Indeed, unlike the perfect competition model, 6 countries moderately gain from a 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

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

Figure 4: Welfare Consequences of a Global Tariff War



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

Notes: The horizontal axis in all 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 and the perfect competition model, respectively. 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.

countries, the welfare consequences of this global tariff war are very similar in the two models.[37]

Appendix Tables F.3 and F.4 as well as Tables F.5 and F.6 show in more detail why we 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 slightly 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 F.3, 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

[37] 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 Sweden or Indonesia. 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.

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.[38] 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 Sweden with high import markups relative to export markups, however, workers experience stronger losses than firm owners. Note that Japan and Sweden are the only two countries 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 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 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 5a: countries which disproportionately import higher-markup goods lose less (or even gain) from the global tariff war.[39] For example, for China and Vietnam, the welfare loss in the baseline model is between 1 and 1.7 percent smaller than the welfare loss in the perfect competition model. On the other hand, for Australia and Norway, the welfare loss in the baseline model is nearly 2 percent larger than the welfare loss in the perfect competition model.

[38] 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.

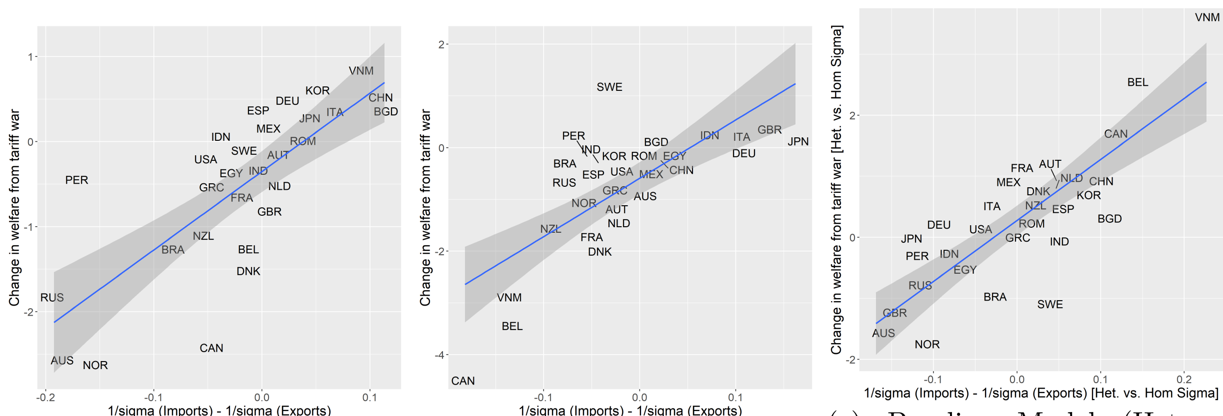
[39] Moreover, as Appendix Figure F.1 shows, the welfare change from the global tariff war in the baseline model relative to that under perfect competition is increasing in the difference between the average import and export markup.

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	-2.475	-1.252	-2.699	1.475	-0.615	-2.108	1.492
Austria	-0.247	-1.351	-0.831	1.935	-0.885	-2.806	1.920
Bangladesh	0.348	-0.141	0.276	0.212	-0.140	-0.351	0.211
Belgium	-1.170	-2.615	-2.117	3.561	-1.683	-5.224	3.541
Brazil	-1.173	-0.555	-1.167	0.549	-0.489	-1.042	0.553
Canada	-2.514	-2.700	-2.737	2.923	-1.603	-4.547	2.944
China	0.614	-0.382	0.404	0.592	-0.241	-0.834	0.593
Denmark	-1.426	-2.886	-1.978	3.438	-1.427	-4.861	3.434
France	-0.562	-1.555	-1.032	2.025	-0.762	-2.779	2.017
Germany	0.390	-0.977	-0.207	1.574	-0.545	-2.118	1.573
Greece	-0.536	-0.510	-0.724	0.698	-0.322	-1.021	0.700
India	-0.244	-0.150	-0.308	0.214	-0.153	-0.367	0.215
Indonesia	-0.055	-0.772	-0.467	1.184	-0.498	-1.680	1.181
Italy	0.444	-0.654	0.026	1.072	-0.322	-1.389	1.067
Japan	0.184	-0.215	0.066	0.333	-0.111	-0.443	0.332
Rep. of Korea	0.510	-0.261	0.364	0.407	-0.201	-0.606	0.405
Mexico	0.247	-1.499	-0.169	1.915	-0.760	-2.666	1.907
Netherlands	-0.612	-1.518	-1.323	2.228	-0.895	-3.120	2.225
New Zealand	-1.011	-1.316	-0.917	1.222	-0.791	-2.015	1.224
Norway	-2.531	-1.556	-2.843	1.869	-0.719	-2.606	1.887
Peru	-0.355	-0.247	-0.364	0.256	-0.098	-0.354	0.256
Romania	0.012	-0.607	-0.243	0.862	-0.323	-1.181	0.858
Russia	-1.735	-0.810	-1.758	0.833	-0.434	-1.270	0.837
Vietnam	0.745	-1.481	0.463	1.764	-1.020	-2.760	1.740
Spain	0.277	-0.448	-0.066	0.791	-0.281	-1.068	0.786
Sweden	-0.197	-0.751	-0.643	1.196	-0.510	-1.705	1.194
Egypt	-0.461	-0.373	-0.461	0.373	-0.303	-0.676	0.374
United Kingdom	-0.901	-1.641	-1.099	1.839	-0.863	-2.700	1.837
USA	-0.298	-0.449	-0.469	0.621	-0.252	-0.871	0.618
ROW	-1.701	-2.191	-2.119	2.610	-1.040	-3.684	2.643

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 (49), 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 5: 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.

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.[40] 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, Figure 5b repeats the welfare results in the baseline model with heterogeneous elasticities. The horizontal axis in Figure 5c 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 between 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 Vietnam, 2.4 percentage points for Belgium, or 1.8 percentage points in Canada.

On the other hand, as Figure 5c shows, incorporating cross-country heterogeneity in elasticities of substitution can also raise the gap between import and export markups and for these countries, the welfare loss from a global tariff war is attenuated in the baseline model. For instance, the welfare loss from a global tariff war in the baseline model with heterogeneity is smaller than that without heterogeneity by about 1.6 percentage points for Norway and Australia and close to 1 percentage points for Russia and the UK.

Importantly, in addition to such quantitative differences, introducing heterogeneous elasticities can even change the qualitative consequences of a global tariff war. Specifically, while China, South Korea, and Mexico 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 also worth mentioning that there are three countries that gain from this global tariff war in the baseline model with or without heterogeneous elasticities: Germany, Italy, and Japan. For these three countries, as Figures 5a and 5b show, the average difference between the import and export markup is relatively high, with or without

[40]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 (40). In a model with one-tier CES structure, however, these elasticities would not have a quantitative impact at all.

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 5a and 5c, once this variation is removed, we obtain more moderate welfare effects for e.g. Belgium, Vietnam, and Canada, and welfare changes range only from -2.5% to 0.7% compared to -4.4% to 1.0% in the full model. Interestingly, in this case, we find that poorer economies such as Vietnam, Bangladesh, 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 5a 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 F.5 and F.6 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 in the homogeneous-elasticity case 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 Magnitude of and Sectoral Heterogeneity in Trade Elasticities. As the simple model in Section 3 suggests, the profit-shifting channel is stronger when productivities across countries are less dispersed, i.e., if trade elasticities θ are larger. We examine this relationship quantitatively in two ways: (1) We raise all trade elasticities by 50% and perform the same global tariff war counterfactual experiment as above and (2) we use the estimates for $\theta^{j(k)}$ reported by CEPII (Fontagné, Guimbard and Orefice (2019) which are significantly larger than those used in the baseline specification. We find that both approaches result in very similar predictions, and hence describe only the second approach in detail.

As summarized in Table F.7, we find that the declines in welfare in the perfect competition case are noticeably larger in this specification, which is expected given that trade is significantly more elastic in this case. We also find that the profit-shifting channel is even more prominent now, with countries such as Canada or Belgium e.g. experiencing welfare declines close to 7%, nearly twice as large as in the baseline model. Overall however, the implications of this counterfactual are very similar to before and net exporters of high-markup goods continue to experience large welfare declines compared to net importers, which again suffer smaller losses or even gains compared to the perfect-competition case.

In order to assess the importance of sectoral heterogeneity in the Frechet parameter θ, we also recomputed the impact of tariffs when θ in all sectors is set equal to the median value that we estimated in Section 5. Appendix Table F.8 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 about -0.5 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 $\theta^{j(k)}$.[41]

As mentioned above, Armington-type frameworks (e.g. Ossa, 2014) impose a perfect positive correlation between import demand elasticities and trade elasticities, i.e. such that $\theta = \sigma - 1$. Under this assumption, sectors with high markups (i.e., low σ) necessarily face low trade elasticities, which in turn limits the role of profit shifting. To quantitatively explore how this assumption influences profit shifting and welfare, we use U.S. import demand elasticities for all countries and assume that trade elasticities are equal to $\sigma - 1$. We then perform the same global tariff war exercise which delivers the results presented in Table F.9. We compare these results with Table F.7 based on CEPII trade elasticities, to work with comparable magnitudes for trade elasticities (since we showed above that large trade elasticities tend to magnify the role of profit shifting). Comparing Tables F.7 and F.9 shows that while both frameworks have relatively similar results under perfect competition, the results differ in a meaningful way under imperfect competition. For example, while welfare in Belgium and Canada declines by 7% and increases by 1.6% in the UK in our framework (Table F.7), these numbers change to 3.5% loss and 1.8% loss, respectively, when imposing $\theta = \sigma - 1$ (Table F.9). These predictions highlight that imposing trade elasticities to be perfectly correlated with import demand elasticticies limits the profit-shifting channel to a large extent.

Employing Elasticities Implied by ORBIS Markups. As a final robustness check, we also utilized an alternative approach to infer the elasticity of substitution $\sigma_n^{j(k)}$ based on firm-

[41] 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.

level markups that we estimate using the ORBIS database, by employing the De Loecker and Warzynski (2012) methodology. Specifically, we use that the optimal CES markup equals $\sigma_n^{j(k)}/(\sigma_n^{j(k)} - 1)$ to back out the values for $\sigma_n^{j(k)}$ which rationalize the observed markups in the data. To infer $\sigma_n^{j(k)}$, we first estimate the markup that each firm in sector $j(k)$ in country n charges in its domestic market. To make sure our estimates are not contaminated by markups that exporting firms charge in other countries, we drop the largest 20% of firms in each sector-country.[42] We then take cross-firm average markup within each sector-country to infer $\sigma_n^{j(k)}/(\sigma_n^{j(k)} - 1)$.[43] One drawback of this approach is that ORBIS only features reliable data on 8 countries in our sample which limits the scope of this alternative counterfactual compared to the baseline case. Nevertheless, the results of this alternative specification assess if and to what extent the quantitative results hinge on the use of the Feenstra-method or if they are robust to using other methods. We find that the main insights from the baseline model still hold in this specification as well: Under perfect competition, each country experiences welfare losses ranging from 0.3 to 1.8 percent, but once markups are taken into account, changes in welfare are more dispersed, ranging from a 3% loss to a gain of 1.5%. In addition, the correlation between the welfare change from this global tariff war in the baseline model versus that in the perfect competition model and the difference between average import and export markups is even stronger now, with nearly 0.88.

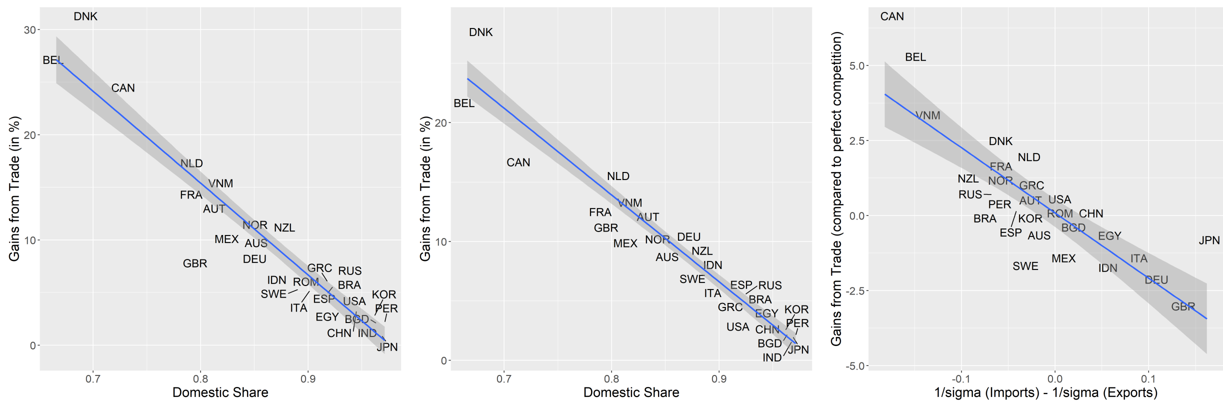
Gains from Trade. As an extreme case of a global tariff war, we move all tariffs to infinity to calculate the gains from trade, i.e., percentage changes in welfare as we move from the observed trade volumes in 2015 to autarky. Appendix E outlines the procedure to numerically solve for the gains from trade, and Appendix Table E.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 6a. Moreover, comparing the gains from trade in the baseline model with those in the perfect competition model (Figure 6c) 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. Moreover, by going to autarky, the price index rises a lot in all countries, and therefore real profits even for these net-importers of high-markup goods fall, with the only exception being Japan.

Interestingly, however, we find that the gains from trade tend to be less sensitive to profit

[42] We would ideally drop the exporters from our sample, but export information in ORBIS data has many missing values and are not reliable.

[43] For ROW, we use the median elasticity in the respective sector across all countries.

Figure 6: The Gains from Trade



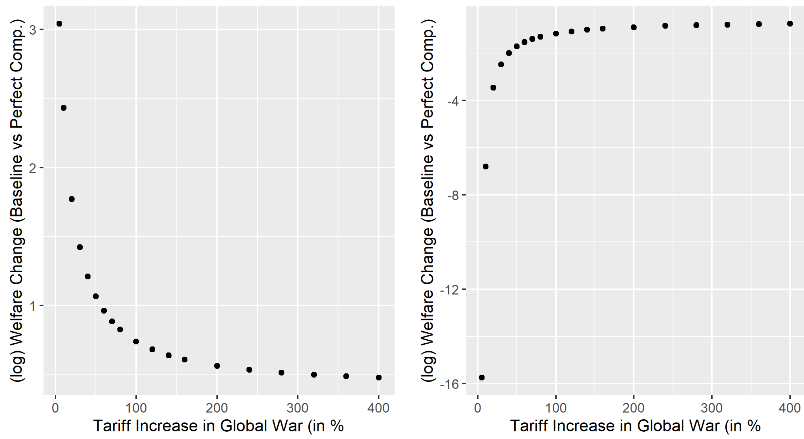
(a) Baseline Model (b) Perfect Competition (c) Baseline vs. Perfect Comp.

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.

shifting than the welfare consequences of tariff wars, as evident from the fact that for many countries, the perfect and imperfect competition settings have relatively 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.

To make this point more clear, Figure 7 plots the percentage difference between the welfare change in the baseline model versus that under perfect competition as function of the imposed tariff in a global trade war for both Canada and Japan. This difference becomes smaller in absolute value for larger tariffs: For smaller tariffs, the welfare decline is about 3 times larger in the baseline model for Canada and about 50% higher when tariffs are raised by 400%. This relationship suggests that profit shifting is particularly relevant for low tariffs and becomes gradually less important afterwards. This pattern also holds for a country like Japan which gains for moderate tariff levels: Also here, the baseline and perfect competition case become more aligned the larger the imposed tariffs are. The intuition behind these results is that with large increases in tariffs (or in the extreme case of going to autarky) the rise in the price index would be the primary determinant, dominating all other forces including the profit-shifting channel.

Figure 7: Difference between the Baseline and Perfect Competition Model



(a) Canada (b) Japan

Notes: This plot shows the percentage difference between the welfare change in the baseline model versus that under perfect competition (y-axis) as function of the imposed tariff in a global trade war (x-axis) for both Canada and Japan.

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 E.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 E.1 and E.2 shows that for countries that abstracting away from the cross-country heterogeneity in these elasticities underestimates (overestimates) the export relative to import markups, the gains from trade would be underestimated (overestimated). While, for example, the gains from trade for Belgium, Canada, and Vietnam are underestimated, ignoring the cross-country heterogeneity in these elasticities overestimates the gains from trade for the U.K., Australia, and Norway (look at the x-axis in Figure 5c).

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 F.10 reports the results. Interestingly, the U.S. gains in the baseline model are significantly larger than those under perfect competition (0.41 vs 0.34%). Moreover, note that these larger gains for the U.S. in the baseline model are not due to a larger tariff revenue; indeed, the change in tariff revenue is identical in these two models. Instead, a unilateral tariff increase in the baseline model mainly 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 4, we employed a nested-CES structure in which firms compete in 4-digit HS categories, and therefore, face 4-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 4-digit, HS categories. This modified model ("HS2 model," hereafter) along with the equilibrium conditions is outlined in Appendix D. To perform the counterfactual experiments in this modified model, we use the same trade elasticities as before. Appendix Table F.11 reports the results for the global tariff war studied above and shows that overall, the results are quite similar to before: Canada, Belgium, and Vietnam for example also here experience the largest welfare losses and welfare changes are in general more spread out in the baseline model than under perfect competition. These findings suggest that our main results are not specific to the chosen aggregation level and hold more broadly.[44]

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.

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. imports 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

[44] It is important to note that these results are not due to differences in trade elasticities. Since we estimate sectoral trade elasticities on the 2-digit level in the baseline specification, the ones used for this modified model are the same.

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 0.032 and 0.056 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 0.032 for the U.S. almost 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 0.072 percent, China gains by 0.014 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 (-0.072 percent in baseline versus -0.032 percent in perfect competition). The rise in real profit in China, on the other hand, compensates the decline in real wage, which in turn makes 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 0.26 compared to 0.33 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 F.12 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 exported by the U.S. are on average significantly higher-markup goods than those which it imports for the 5 largest broadly defined sectors in the dataset (machinery, furniture, toys, and footwear). This means that for more than 60% of observed trade flows, 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

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	0.000	-0.001	0.001	0.000	-0.002	-0.002	0.000
Austria	-0.000	0.001	-0.002	0.000	0.003	0.002	0.000
Bangladesh	0.001	0.001	0.000	0.000	0.001	0.001	0.000
Belgium	0.002	0.000	0.001	0.000	0.001	0.000	0.000
Brazil	0.002	0.001	0.001	0.001	0.001	0.001	0.001
Canada	0.008	0.009	-0.002	0.001	0.014	0.013	0.001
China	0.014	-0.064	0.037	0.041	-0.056	-0.097	0.041
Denmark	0.004	0.003	0.001	0.000	0.005	0.005	0.000
France	0.006	0.002	0.004	0.000	0.003	0.003	0.000
Germany	0.003	0.002	0.000	0.000	0.003	0.003	0.000
Greece	0.001	0.000	0.000	0.000	0.001	0.001	0.000
India	0.001	0.000	0.001	0.000	0.001	0.001	0.000
Indonesia	0.001	0.002	-0.000	-0.000	0.003	0.003	-0.000
Italy	0.001	0.001	0.000	0.000	0.001	0.001	0.000
Japan	-0.000	0.001	-0.001	0.000	0.002	0.002	0.000
Rep. of Korea	0.001	0.001	-0.000	0.000	0.001	0.001	0.000
Mexico	0.010	0.014	-0.005	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	-0.001	-0.001	0.000	-0.000	-0.001	-0.001	-0.000
Norway	0.002	0.002	0.000	0.000	0.003	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	0.001	0.000
Russia	0.003	0.000	0.003	-0.000	0.000	0.001	-0.000
Vietnam	0.010	0.007	0.003	0.000	0.010	0.009	0.000
Spain	0.001	0.000	0.001	0.000	0.001	0.001	0.000
Sweden	0.000	0.001	-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	0.002	0.002	-0.000	0.000	0.004	0.003	0.000
USA	-0.072	-0.058	-0.095	0.081	-0.032	-0.113	0.081
ROW	0.007	0.004	0.003	0.000	0.007	0.006	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 (49), 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.

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 Russia. However, also the 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. Intuitively, this is due to the U.S. experiencing greater income losses in the baseline model which translate into stronger declines in exports by Canada and Mexico to the U.S. This in turn partially offsets the more sizeable welfare gains found under perfect competition. The opposite, however, is true for Russia, which exports more to China than to the U.S. and which therefore indirectly benefits from China's gains through profit shifting.

A Uniform U.S.-China Tariff War. So far we examined the welfare consequences of the observed U.S.-China tariff war in which the U.S. and China imposed additional tariffs on a range of targeted industries. In this observed tariff war, some industries are hence taxed more than others. To study to what extent variation across sectors is responsible for the findings of Table 5, we quantify how the results would change if the U.S. and China instead raise all tariffs against each other uniformly by 20 percentage points across all 4-digit sectors. This exercise is particularly helpful to understand to what extent the results of the factual war are due to the composition of goods that the U.S. and China import from each other, as opposed to the degree to which both countries actively targeted high- versus low-markup industries.

As Table F.13 reports, we find that in the baseline model, both the welfare losses experienced by the U.S. (-0.09% versus -0.07%) and the gains experienced by China (0.024% versus 0.014%) are even larger than in the factual war. This result is due to the inverse elasticity of the goods on which the U.S. and China place tariffs (weighted by trade volume and the tariff rate) being 0.24 for the U.S. and 0.34 for China compared to 0.26 and 0.33 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 factual U.S.-China tariff war experiment, but we assume all countries share the same substitution elasticities as in the U.S. Appendix Table F.14 reports the results. As discussed before, elasticities of substitution play almost no 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 0.07 percent in the heterogeneous model, now falls by 0.11 percent, and China, which used to gain by 0.01 percent in the heterogeneous model, now gains by 0.06 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 F.14 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 F.14 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 0.33, this goes up to 0.41 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 for U.S. neighbors. While, as shown in Table F.14, Canada and Mexico still gain from this tariff war in in the baseline model with homogeneous elasticities, these gains are less pronounced. This result is due to fact that the U.S. now experiences even stronger declines in income than before, which translates into greater reductions in exports from Canada and Mexico. Overall however, third-party countries are only moderately affected by the U.S.-China trade war, as was the case in the baseline model.

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 50% highest- (lowest-) markup sectors with a tariff of 37% (additional to pre-war tariffs). In this counterfactual tariff war, the average tariffs imposed by the U.S. and China match those in the factual 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 0.57 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 are nearly reversed: while China now experiences sizable losses from this counterfactual tariff war, the U.S. slightly gains. 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. (which tends to magnify their gains) and (2) more easily export low-markup goods to and import high-markup goods from China (which tends to mitigate their gains). 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

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

Countries	Baseline Model				Perfect Competition Model		
	welfare	wage	profit	tariff	welfare	wage	tariff
Australia	0.012	0.008	0.004	-0.000	0.014	0.014	-0.000
Austria	0.001	0.000	0.001	-0.000	0.000	0.000	-0.000
Bangladesh	-0.002	-0.001	-0.001	-0.001	-0.002	-0.002	-0.001
Belgium	0.009	0.006	0.003	0.000	0.010	0.010	0.000
Brazil	0.004	0.004	-0.001	0.001	0.008	0.007	0.001
Canada	0.022	0.016	0.007	-0.001	0.019	0.020	-0.001
China	-0.115	-0.053	-0.111	0.049	-0.033	-0.082	0.049
Denmark	-0.007	-0.002	-0.004	-0.000	-0.003	-0.003	-0.000
France	-0.003	0.004	-0.007	-0.000	0.006	0.006	-0.000
Germany	0.000	0.002	-0.002	-0.000	0.003	0.003	-0.000
Greece	-0.002	-0.001	-0.001	-0.000	-0.001	-0.001	-0.000
India	-0.002	-0.001	-0.001	0.000	-0.001	-0.001	0.000
Indonesia	-0.002	-0.000	-0.002	0.001	0.001	0.000	0.001
Italy	-0.000	-0.001	0.001	-0.000	-0.001	-0.001	-0.000
Japan	0.002	0.001	0.001	0.000	0.002	0.002	0.000
Rep. of Korea	0.006	0.004	0.001	0.000	0.006	0.005	0.000
Mexico	-0.007	-0.003	-0.002	-0.002	-0.008	-0.006	-0.002
Netherlands	0.000	0.002	-0.002	-0.000	0.004	0.004	-0.000
New Zealand	0.012	0.007	0.004	0.001	0.010	0.010	0.001
Norway	-0.000	0.002	-0.002	-0.000	0.003	0.003	-0.000
Peru	0.001	0.001	0.000	-0.000	0.001	0.001	-0.000
Romania	-0.001	-0.000	-0.000	-0.000	-0.001	-0.001	-0.000
Russia	-0.004	0.001	-0.005	0.001	0.002	0.002	0.001
Vietnam	0.003	-0.005	0.008	-0.000	-0.007	-0.006	-0.000
Spain	-0.001	-0.000	-0.001	-0.000	-0.000	0.000	-0.000
Sweden	0.001	0.000	0.001	-0.000	0.000	0.001	-0.000
Egypt	0.001	-0.000	0.001	-0.000	-0.000	0.000	-0.000
United Kingdom	-0.003	0.001	-0.003	-0.000	0.001	0.002	-0.000
USA	0.010	-0.044	0.033	0.021	-0.064	-0.085	0.021
ROW	-0.003	0.008	-0.011	-0.001	0.014	0.013	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 (49), 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.

overall stronger effect on welfare in Canada than the change in trade with China, due to the country's proximity to the former. For Vietnam and Russia, however, the result is reversed, as these countries are 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. imposes 23% tariffs (additional to pre-war tariffs) on its 80% largest-markup sectors, in which case, the average tariff imposed by the U.S. again matches that in the factual war. As evident from Appendix Table F.15, we find that this policy would not have resulted in welfare gains for the U.S. but would have still lowered its welfare losses by about 17%. China, on the other hand, experiences losses of nearly 0.06 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.

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 Proof of the Proposition

This section proves the proposition stated in Section 3. First, we show that the profit-shifting channel reduces welfare in Domestic economy, i.e., we show $\frac{\sigma_L}{\sigma_L-1}(1-(\frac{\alpha_L}{\sigma_L}+\frac{\alpha_H}{\sigma_H}))<1$. To see that, note that since $\sigma_L>\sigma_H$, then $1-(\frac{\alpha_L}{\sigma_L}+\frac{\alpha_H}{\sigma_H})<1-(\frac{\alpha_L}{\sigma_L}+\frac{\alpha_H}{\sigma_L})=\frac{\sigma_L-1}{\sigma_L}$, where the equality uses the fact that $\alpha_H+\alpha_L=1$. Therefore, $\frac{\sigma_L}{\sigma_L-1}(1-(\frac{\alpha_L}{\sigma_L}+\frac{\alpha_H}{\sigma_H}))<\frac{\sigma_L}{\sigma_L-1}\frac{\sigma_L-1}{\sigma_L}=1$. In a similar fashion, we show that the profit-shifting channel raises welfare in Foreign economy, i.e., $\frac{\sigma_H}{\sigma_H-1}(1-(\frac{\alpha_L^*}{\sigma_L}+\frac{\alpha_H^*}{\sigma_H}))>1$.

Next, note that since $w^*>1$, the Foreign economy always gains from trade, since both price and profit-shifting channels are welfare-improving in this country. For the Domestic country to gain from trade, however, since $\frac{\sigma_L}{\sigma_L-1}(1-(\frac{\alpha_L}{\sigma_L}+\frac{\alpha_H}{\sigma_H}))<1$, the Foreign productivity A_H^* has to be large enough:

$$\frac{U^*_{trade}}{U^*_{aut}}>1 \iff A_H^*>\frac{w^*}{[\frac{\sigma_L}{\sigma_L-1}(1-(\frac{\alpha_L}{\sigma_L}+\frac{\alpha_H}{\sigma_H}))]^{1/\alpha_H}}=\frac{\frac{\alpha_H}{\alpha_L^*}\frac{\frac{\sigma_L}{\sigma_L-1}}{\frac{\sigma_H}{\sigma_H-1}}}{[\frac{\sigma_L}{\sigma_L-1}(1-(\frac{\alpha_L}{\sigma_L}+\frac{\alpha_H}{\sigma_H}))]^{1/\alpha_H}}$$

where the equality uses the equilibrium wage (12) under free trade. Intuitively, this condition states that the price channel has to be strong enough to dominate the profit-shifting channel.

B 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:

$$Pr[c_{in}^{j(k)}(\omega)<c]=1-e^{-\lambda_{in}^{j(k)}c^{\theta^{j(k)}}} \tag{55}$$

where, $\lambda_{in}^{j(k)}=T_i^{j(k)}(w_i\tau_{in}^{j(k)})^{-\theta^{j(k)}}$. Given this and using equation (27), the lowest price of a variety in country n will also have a Fréchet distribution:

$$Pr[p_n^{j(k)}<p]=1-\Pi_{i=1}^N Pr\big(c_{in}^{j(k)}\geq\frac{\sigma_n^{j(k)}-1}{\sigma_n^{j(k)}}p\big) \tag{56}$$

and using equation (55) we obtain

$$Pr[p_n^{j(k)} < p] = \left(1 - e^{-\Phi_n^{j(k)} p^{\theta^{j(k)}}}\right) \tag{57}$$

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 (24) and (57), the price index is given as

$$P_n^{j(k)^{1-\sigma_n^{j(k)}}} = \int p^{1-\sigma_n^{j(k)}} p^{\theta^{j(k)}-1} \theta^{j(k)} \Phi_n^{j(k)} e^{-\Phi_n^{j(k)} p^{\theta^{j(k)}}} dp \tag{58}$$

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

$$P_n^{j(k)^{1-\sigma_n^{j(k)}}} = \int \Phi_n^{j(k)^{\frac{\sigma_n^{j(k)}-1}{\theta^{j(k)}}}} x^{\frac{1-\sigma_n^{j(k)}}{\theta^{j(k)}}} e^{-x} dx \tag{59}$$

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

$$P_n^{j(k)} = A_n^{j(k)} [\sum_{i=1}^N T_i^{j(k)} (w_i \tau_{in}^{j(k)})^{-\theta^{j(k)}}]^{\frac{-1}{\theta^{j(k)}}} \tag{60}$$

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

$$X_{in}^{j(k)} = Pr\left[c_{in}^{j(k)} \leq \min_{h \neq i} c_{hn}^{j(k)}\right] X_n^{j(k)} \tag{61}$$

where $c_{in}^{j(k)} = w_i \tau_{in}^{j(k)} / z_i^{j(k)}$. Using equation (55), we derive equation (29) in the paper:

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

C 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 (36).

iii) Use equation (37) to compute $\hat{\pi}_{in}^{j(k)}$.

iv) Use the system of equations (40)-(43) to solve for counterfactual expenditures $X_n^{'j(k)}$.

v) Check the trade balance equation (44). 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 $X_n^{'j(k)}$, we use the equations (41)-(43) into (40) to write:

$$X_n^{'j(k)} = \frac{\alpha_n^k X_n^{j(k)} \hat{P}_n^{j(k)\ 1-\sigma_n^k}}{\sum_{l=1}^{J(k)} \hat{P}_n^{l(k)\ 1-\sigma_n^k} X_n^{l(k)}} \Big[\hat{w}_n w_n L_n + \sum_{k=1}^{K} \sum_{j=1}^{J(k)} \sum_{i=1}^{N} \frac{\pi_{ni}^{'j(k)} X_i^{'j(k)}}{\sigma_i^{j(k)} (1 + t_{ni}^{'j(k)})} + \sum_{k=1}^{K} \sum_{j=1}^{J(k)} \sum_{i=1}^{N} \frac{t_{in}^{'j(k)}}{(1 + t_{in}^{'j(k)})} \pi_{in}^{'j(k)} X_n^{'j(k)} + D_n \Big] \quad (62)$$

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:

$$\Lambda X = \Psi \quad (63)$$

where

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

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:

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

D The Alternative Model: Competing at HS2 Level

The model we develop here is similar to the baseline model presented in Section 4, 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.

D.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.

D.2 Preferences and Demand Schedules

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

$$U_n = \Pi_{k=1}^{K} Q_n^{k\ \alpha_n^k}, \qquad \sum_{k=1}^{K} \alpha_n^k = 1 \quad \forall n \in \{1, ..., N\} \tag{64}$$

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:

$$Q_n^k = [\int r_n^k(\omega)^{\frac{\sigma_n^k - 1}{\sigma_n^k}} d\omega]^{\frac{\sigma_n^k}{\sigma_n^k - 1}} \tag{65}$$

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 (65) implies the following demand function for variety ω of sector k in country n:

$$r_n^k(\omega) = (\frac{p_n^k(\omega)}{\mathcal{P}_n^k})^{-\sigma_n^k} Q_n^k \tag{66}$$

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

$$\mathcal{P}_n^k = [\int p_n^k(\omega)^{1-\sigma_n^k} d\omega]^{\frac{1}{1-\sigma_n^k}} \tag{67}$$

Moreover, given the Cobb-Douglas preferences (64), consumers in country n face the following price index:

$$\mathcal{P}_n = \Pi_{k=1}^{K} (\frac{\mathcal{P}_n^k}{\alpha_n^k})^{\alpha_n^k} \tag{68}$$

D.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

$$\tau_{in}^k = d_{in}^k(1 + t_{in}^k) \tag{69}$$

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

D.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:

$$q_n^k(\omega) = z_n^k(\omega) l_n^k(\omega) \tag{70}$$

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.[1] 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-

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

Stiglitz markup $\frac{\sigma_n^k}{\sigma_n^k-1}$, and the other producers stay out of the market.[2] Hence, the price for variety ω in sector k in country n is

$$p_n^k(\omega) = (\frac{\sigma_n^k}{\sigma_n^k - 1}) \times \min_i \{\frac{w_i \tau_{in}^k}{z_i^k(\omega)}\} \tag{71}$$

where w_i is the wage in country i.

D.5 Trade Shares and Total Income

Similar to what we showed in Appendix B, we can use the price equation (71) along with the properties of Fréchet distribution to derive the price index $\mathcal{P}_n^k$ in (67):

$$\mathcal{P}_n^k = A_n^k [\sum_{i=1}^{N} T_i^k (w_i \tau_{in}^k)^{-\theta^k}]^{\frac{-1}{\theta^k}} \tag{72}$$

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 B, we can derive the share of country i in country n's expenditure on sector k as

$$\frac{X_{in}^k}{X_n^k} \equiv \pi_{in}^k = \frac{T_i^k (w_i \tau_{in}^k)^{-\theta^k}}{\sum_{h=1}^N T_h^k (w_h \tau_{hn}^k)^{-\theta^k}} \tag{73}$$

Now we derive an equation for expenditure X_n^k. Let I_n denote total income in country n. Given the Cobb-Douglas preferences (64), consumers in country n spend the fraction α_n^k of their income on sector k:

$$X_n^k = \alpha_n^k I_n \tag{74}$$

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

$$I_n = w_n L_n + Y_n + R_n + D_n \tag{75}$$

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

[2] 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.

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

$$Y_n = \sum_{k=1}^{K}\sum_{i=1}^{N}\frac{\pi_{ni}^k X_i^k}{\sigma_i^k(1+t_{ni}^k)} \tag{76}$$

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

$$R_n = \sum_{k=1}^{K}\sum_{i=1}^{N}\frac{t_{in}^k}{(1+t_{in}^k)}\pi_{in}^k X_n^k \tag{77}$$

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

$$\sum_{k=1}^{K}\sum_{i=1}^{N}\frac{\pi_{in}^k X_n^k}{(1+t_{in}^k)} - D_n = \sum_{k=1}^{K}\sum_{i=1}^{N}\frac{\pi_{ni}^k X_i^k}{(1+t_{ni}^k)} \tag{78}$$

It can be shown that trade balance (78) implies labor market clearing. To see that, sum over all sectors k in equation (74), and use the trade balance to write:

$$w_n L_n = \sum_{k=1}^{K}\sum_{i=1}^{N}\frac{\pi_{ni}^k X_i^k}{(1+t_{ni}^k)} - Y_n = \sum_{k=1}^{K}\sum_{i=1}^{N}\frac{(\sigma_i^k-1)\pi_{ni}^k X_i^k}{\sigma_i^k(1+t_{ni}^k)} \tag{79}$$

D.6 Equilibrium

Equilibrium Definition Given Fréchet 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 (72), (73), (74), (75), (76), (77), and (78).

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 Fréchet 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 (72) under τ' by the one under τ, and then use (73) to remove

T_n^k:

$$\hat{\mathcal{P}}_n^k = [\sum_{i=1}^{N} \pi_{in}^k (\hat{w}_i \hat{\tau}_{in}^k)^{-\theta^k}]^{\frac{-1}{\theta^k}} \tag{80}$$

Then, we use the price index (72) in the trade shares (73) to write the trade shares in relative terms:

$$\hat{\pi}_{in}^k = [\frac{\hat{w}_i \hat{\tau}_{in}^k}{\hat{\mathcal{P}}_n^k}]^{-\theta^k} \tag{81}$$

Next, we write total expenditure (74) under the counterfactual trade frictions:

$$X_n'^k = \alpha_n^k I_n' \tag{82}$$

Using income equation (75), we can write income under counterfactual trade frictions as follows:

$$I_n' = \hat{w}_n w_n L_n + Y_n' + R_n' + D_n \tag{83}$$

where

$$Y_n' = \sum_{k=1}^{K} \sum_{i=1}^{N} \frac{\pi_{ni}'^k X_i'^k}{\sigma_i^k (1 + t_{ni}'^k)} \tag{84}$$

$$R_n' = \sum_{k=1}^{K} \sum_{i=1}^{N} \frac{t_{in}'^k}{(1 + t_{in}'^k)} \pi_{in}'^k X_n'^k \tag{85}$$

and we assume trade deficits remain unchanged. Similarly, use trade balance equation (78) to write trade balance under counterfactual trade frictions

$$\sum_{k=1}^{K} \sum_{i=1}^{N} \frac{\pi_{in}'^k X_n'^k}{(1 + t_{in}'^k)} - D_n = \sum_{k=1}^{K} \sum_{i=1}^{N} \frac{\pi_{ni}'^k X_i'^k}{(1 + t_{ni}'^k)} \tag{86}$$

where we again assume trade deficits remain unchanged.

Equilibrium Definition in Relative Terms Given Frećhet shape parameters θ^k, elasticities of substitution σ_n^k, Cobb-Douglas shares α_n^k, total expenditures X_n^k, trade shares π_{in}^k, labor endowments L_n, relative trade frictions $\hat{\tau}_{in}^k$, and Ad Valorem tariffs $t_{in}'^k$, an equilibrium is characterized by a set of relative wages $\{\hat{w}_n\}_{n=1}^N$ that satisfy equilibrium conditions (80), (81), (82), (83), (84), (85), and (86).

D.7 Solving for Equilibrium

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

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

ii) Compute $\hat{P}_n^{j(k)}$ using equation (80).

iii) Use equation (81) to compute $\hat{\pi}_{in}^{j(k)}$.

iv) Use the system of equations (82)-(85) to solve for counterfactual expenditures $X_n^{\prime j(k)}$.

v) Check the trade balance equation (86). If it is satisfied, we are done. Otherwise, we update our guess on $\hat{w}_n$ and go back to step (ii).

E Gains from Trade

To numerically compute the gains from trade, we use the equilibrium conditions in relative terms derived in Section 4.6, and move the trade cost between countries to infinity. So we can write the price equation (36) as

$$\hat{P}_n^{j(k)} = [\pi_{nn}^{j(k)}]^{\frac{-1}{\theta^{j(k)}}} \tag{87}$$

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 (40) in the text:

$$X_n^{\prime j(k)} = \alpha_n^k I_n' \frac{\hat{P}_n^{j(k)\ 1-\sigma_n^k} X_n^{j(k)}}{\sum_{l=1}^{J(k)} \hat{P}_n^{l(k)\ 1-\sigma_n^k} X_n^{l(k)}} \tag{88}$$

where

$$I_n' = w_n L_n + Y_n' \tag{89}$$

$$Y_n' = \sum_{k=1}^{K} \sum_{j=1}^{J(k)} \frac{X_n^{\prime j(k)}}{\sigma_n^{j(k)}} \tag{90}$$

We solve the system of equations (88)-(90) 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 C.

After solving for the counterfactual expenditures, we find counterfactual incomes using equation (89). To find counterfactual welfare (i.e., real income), we use the change in sectoral price indices in equation (39):

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

Table E.1: Gains from Trade: the (opposite 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	8.988	5.482	3.209	0.296	9.378	9.082	0.296
Austria	12.254	6.496	5.498	0.260	11.566	11.306	0.260
Bangladesh	2.069	1.257	0.550	0.262	2.196	1.934	0.262
Belgium	27.900	13.370	14.060	0.470	22.341	21.870	0.471
Brazil	5.190	2.807	1.739	0.644	5.311	4.666	0.644
Canada	23.741	12.421	10.976	0.344	17.352	17.007	0.344
China	3.269	2.023	1.023	0.223	3.303	3.080	0.223
Denmark	30.546	17.841	12.256	0.450	28.317	27.867	0.450
France	14.210	7.975	5.936	0.298	12.600	12.301	0.299
Germany	7.885	5.982	1.624	0.279	9.753	9.474	0.279
Greece	6.018	3.159	2.766	0.093	5.264	5.171	0.093
India	1.885	1.036	0.684	0.165	1.588	1.423	0.165
Indonesia	6.985	4.820	1.751	0.415	8.457	8.042	0.415
Italy	5.206	3.816	1.230	0.160	6.358	6.198	0.160
Japan	0.921	1.050	-0.192	0.063	1.996	1.934	0.063
Rep. of Korea	2.771	1.745	0.883	0.144	2.521	2.378	0.144
Mexico	9.373	7.032	2.188	0.153	10.531	10.378	0.153
Netherlands	16.568	8.280	8.000	0.288	14.873	14.585	0.288
New Zealand	10.457	6.609	3.658	0.190	9.480	9.290	0.190
Norway	11.772	6.391	5.068	0.313	10.863	10.550	0.313
Peru	2.172	1.388	0.746	0.038	2.097	2.059	0.038
Romania	5.972	3.433	2.392	0.147	5.720	5.573	0.147
Russia	6.258	3.228	2.678	0.352	5.558	5.206	0.352
Vietnam	16.173	8.504	6.999	0.669	12.563	11.894	0.669
Spain	5.585	2.918	2.527	0.141	5.415	5.274	0.141
Sweden	5.309	2.731	2.435	0.143	7.241	7.097	0.144
Egypt	3.480	2.004	1.186	0.291	3.883	3.592	0.290
United Kingdom	8.563	6.186	2.058	0.320	11.842	11.523	0.320
USA	4.206	1.861	2.250	0.096	3.701	3.605	0.095
ROW	15.410	8.678	5.890	0.842	15.323	14.486	0.838

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 (49), 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.

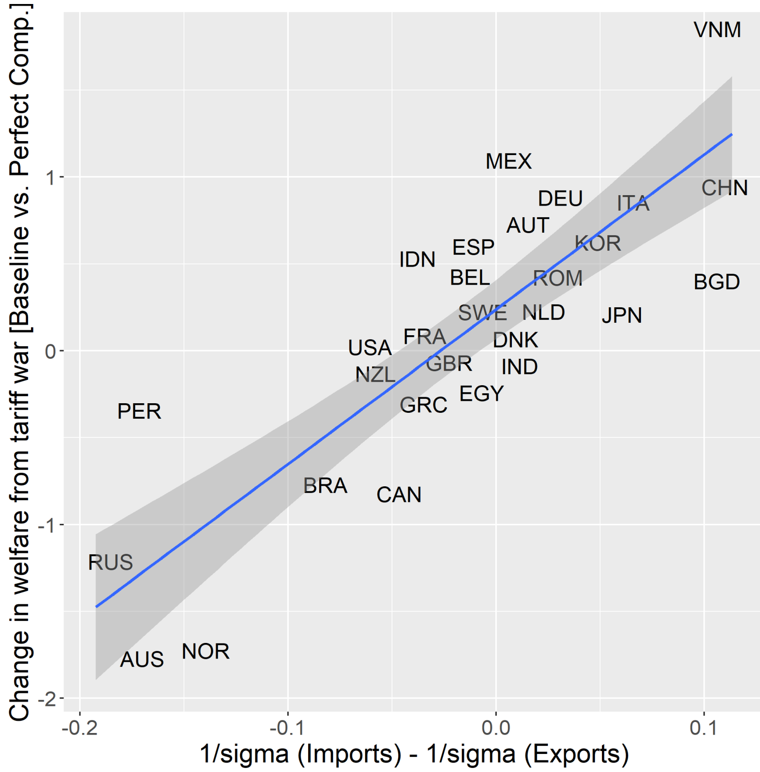
Table E.2: Gains from Trade (Homogeneous Elasticities): the (opposite of) welfare changes (%) as we move from the observed trade data in 2015 to autarky

Countries	Baseline Model				Perfect Competition Model		
	welfare	wage	profit	tariff	welfare	wage	tariff
Australia	13.887	5.429	8.162	0.296	9.265	8.969	0.296
Austria	12.268	5.580	6.428	0.260	11.886	11.626	0.260
Bangladesh	1.279	0.791	0.225	0.263	2.242	1.979	0.262
Belgium	23.267	11.325	11.471	0.472	23.189	22.717	0.471
Brazil	7.028	2.483	3.898	0.647	5.278	4.632	0.646
Canada	21.096	10.988	9.760	0.349	18.704	18.356	0.349
China	1.689	1.397	0.071	0.220	3.297	3.075	0.222
Denmark	28.787	16.346	11.991	0.451	27.976	27.525	0.451
France	12.688	6.738	5.651	0.299	12.352	12.053	0.299
Germany	8.805	4.299	4.229	0.277	9.669	9.391	0.278
Greece	6.051	2.562	3.396	0.093	5.220	5.127	0.093
India	1.748	0.576	1.007	0.165	1.576	1.411	0.165
Indonesia	7.926	3.511	4.001	0.415	8.095	7.678	0.416
Italy	5.667	3.025	2.483	0.160	6.623	6.463	0.160
Japan	1.406	0.935	0.408	0.063	1.997	1.934	0.063
Rep. of Korea	1.436	1.050	0.243	0.144	2.593	2.449	0.144
Mexico	9.397	6.032	3.210	0.155	10.969	10.814	0.155
Netherlands	16.741	7.683	8.770	0.288	16.099	15.811	0.288
New Zealand	10.484	6.192	4.103	0.190	9.665	9.475	0.190
Norway	15.480	6.359	8.807	0.315	10.781	10.467	0.314
Peru	2.643	1.441	1.165	0.038	2.098	2.060	0.038
Romania	5.493	2.903	2.442	0.148	5.806	5.658	0.148
Russia	8.910	3.445	5.111	0.355	5.697	5.344	0.353
Vietnam	11.152	7.173	3.312	0.667	14.190	13.521	0.669
Spain	4.582	2.151	2.290	0.141	5.289	5.149	0.141
Sweden	7.573	3.110	4.319	0.144	7.226	7.082	0.144
Egypt	4.410	2.076	2.041	0.293	4.061	3.767	0.293
United Kingdom	12.314	7.091	4.902	0.321	11.976	11.655	0.321
USA	4.307	1.863	2.348	0.096	3.703	3.608	0.096
ROW	17.691	8.829	7.973	0.889	15.511	14.732	0.779

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 (49), 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.

F Additional Figures and Tables

Figure F.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 F.1: Inverse Demand Elasticities and Import/Export Shares for each country's largest sectors

	Imports			Exports		
Country	Product Category (HS2 level)	Share	$1/\sigma$	Product Category (HS2 level)	Share	$1/\sigma$
Australia	Machinery, Mech. Appliances (84)	16.26	.21	Ores, Slag, and Ash (26)	27.49	.37
Australia	Vehicles (87)	12.92	.69	Mineral Fuels/Oils, etc. (27)	26.08	.41
Australia	Mineral Fuels/Oils, etc. (27)	11.21	.35	Precious Stones, Pearls (71)	7.2	.58
Austria	Machinery, Mech. Appliances (84)	13.85	.41	Machinery, Mech. Appliances (84)	18.06	.34
Austria	Vehicles (87)	10.82	.56	Elec. Machinery/Equipment (85)	11.21	.34
Austria	Elec. Machinery/Equipment (85)	10.06	.54	Vehicles (87)	9.41	.32
Bangladesh	Cotton (52)	14.89	.49	Cloth. Accessories, not knitted (62)	41.86	.39
Bangladesh	Mineral Fuels/Oils, etc. (27)	10.87	.53	Cloth. Accessories, knitted (61)	41.4	.35
Bangladesh	Machinery, Mech. Appliances (84)	9.98	.31	Textiles, made up articles, rags (63)	2.88	.38
Belgium	Mineral Fuels/Oils, etc. (27)	12.18	.43	Mineral Fuels/Oils, etc. (27)	11.61	.49
Belgium	Vehicles (87)	11.61	.28	Vehicles (87)	10.61	.42
Belgium	Pharmaceutical Products (30)	9.92	.11	Pharmaceutical Products (30)	9.11	.54
Brazil	Mineral Fuels/Oils, etc. (27)	14.65	.32	Ores, Slag, and Ash (26)	12.94	.44
Brazil	Machinery, Mech. Appliances (84)	14.47	.40	Seeds and Grains (12)	11.25	.38
Brazil	Elec. Machinery/Equipment (85)	11.98	.54	Mineral Fuels/Oils, etc. (27)	8.53	.54
Canada	Vehicles (87)	16.33	.10	Mineral Fuels/Oils, etc. (27)	19.31	.64
Canada	Machinery, Mech. Appliances (84)	15.38	.17	Vehicles (87)	15.06	.19
Canada	Elec. Machinery/Equipment (85)	10.05	.26	Machinery, Mech. Appliances (84)	7.53	.28
China	Elec. Machinery/Equipment (85)	21.8	.38	Elec. Machinery/Equipment (85)	28.97	.26
China	Mineral Fuels/Oils, etc. (27)	12.97	.33	Machinery, Mech. Appliances (84)	17.26	.25
China	Machinery, Mech. Appliances (84)	8.9	.40	Furniture, Bedding, etc. (94)	3.82	.22
Denmark	Machinery, Mech. Appliances (84)	12.64	.27	Machinery, Mech. Appliances (84)	14.02	.27
Denmark	Elec. Machinery/Equipment (85)	10	.47	Pharmaceutical Products (30)	12.37	.57
Denmark	Vehicles (87)	7.99	.22	Elec. Machinery/Equipment (85)	7.91	.36
Egypt	Mineral Fuels/Oils, etc. (27)	13.93	.33	Mineral Fuels/Oils, etc. (27)	28.47	.41
Egypt	Vehicles (87)	8.66	.56	Elec. Machinery/Equipment (85)	6.5	.24
Egypt	Machinery, Mech. Appliances (84)	8.3	.39	Plastics and Articles thereof (39)	5.03	.33
France	Machinery, Mech. Appliances (84)	11.8	.24	Machinery, Mech. Appliances (84)	11.52	.37
France	Mineral Fuels/Oils, etc. (27)	10.61	.22	Vehicles (87)	10.37	.41
France	Vehicles (87)	9.7	.55	Aircraft, Spacecraft (88)	10.17	.40
Germany	Machinery, Mech. Appliances (84)	13.32	.54	Vehicles (87)	19.63	.37
Germany	Elec. Machinery/Equipment (85)	12.57	.57	Machinery, Mech. Appliances (84)	17.69	.29
Germany	Vehicles (87)	9.96	.29	Elec. Machinery/Equipment (85)	9.73	.33
Greece	Mineral Fuels/Oils, etc. (27)	25.94	.35	Mineral Fuels/Oils, etc. (27)	27.34	.62
Greece	Machinery, Mech. Appliances (84)	6.77	.34	Aluminium and Articles thereof (76)	5.93	.49
Greece	Pharmaceutical Products (30)	6.39	.19	Machinery, Mech. Appliances (84)	4.46	.28
India	Mineral Fuels/Oils, etc. (27)	27.55	.25	Precious Stones, Pearls (71)	13.54	.53
India	Precious Stones, Pearls (71)	15.71	.56	Mineral Fuels/Oils, etc. (27)	12.29	.59
India	Elec. Machinery/Equipment (85)	9.46	.44	Machinery, Mech. Appliances (84)	5.44	.27
Indonesia	Mineral Fuels/Oils, etc. (27)	17.62	.29	Mineral Fuels/Oils, etc. (27)	21.12	.43
Indonesia	Machinery, Mech. Appliances (84)	15.72	.52	Animal and Vegetable Oils/Fats (15)	11.94	.43
Indonesia	Elec. Machinery/Equipment (85)	10.9	.55	Elec. Machinery/Equipment (85)	6.67	.31

Notes: Inverse demand elasticity in each HS2 sector is the average of HS4 inverse demand elasticites, weighted by trade volumes.

Table F.2: Inverse Demand Elasticities and Import/Export Shares for each country's largest sectors (cont.)

	Imports			Exports		
Country	Product Category (HS2 level)	Share	$1/\sigma$	Product Category (HS2 level)	Share	$1/\sigma$
Italy	Mineral Fuels/Oils, etc. (27)	12.36	.37	Machinery, Mech. Appliances (84)	19.84	.26
Italy	Machinery, Mech. Appliances (84)	9.63	.53	Vehicles (87)	8.34	.36
Italy	Vehicles (87)	8.98	.36	Elec. Machinery/Equipment (85)	6.21	.32
Japan	Mineral Fuels/Oils, etc. (27)	20.88	.49	Vehicles (87)	20.91	.24
Japan	Elec. Machinery/Equipment (85)	14.69	.70	Machinery, Mech. Appliances (84)	20.05	.30
Japan	Machinery, Mech. Appliances (84)	9.69	.57	Elec. Machinery/Equipment (85)	18.11	.30
Mexico	Elec. Machinery/Equipment (85)	23.14	.32	Vehicles (87)	24.3	.28
Mexico	Machinery, Mech. Appliances (84)	18.04	.32	Elec. Machinery/Equipment (85)	21.7	.19
Mexico	Vehicles (87)	9.69	.23	Machinery, Mech. Appliances (84)	15.83	.18
Netherlands	Mineral Fuels/Oils, etc. (27)	14.92	.48	Mineral Fuels/Oils, etc. (27)	15.85	.44
Netherlands	Machinery, Mech. Appliances (84)	13.33	.29	Machinery, Mech. Appliances (84)	13.04	.30
Netherlands	Elec. Machinery/Equipment (85)	11.98	.23	Elec. Machinery/Equipment (85)	9.45	.37
New Zealand	Vehicles (87)	13.53	.27	Dairy, Eggs, Honey (4)	23.43	.38
New Zealand	Machinery, Mech. Appliances (84)	13.37	.28	Meat and Edible Meat (2)	13.92	.19
New Zealand	Mineral Fuels/Oils, etc. (27)	10.08	.29	Wood and Articles of Wood (44)	8.21	.39
Norway	Machinery, Mech. Appliances (84)	14.55	.37	Mineral Fuels/Oils, etc. (27)	48.88	.47
Norway	Vehicles (87)	10.8	.24	Fish, Seafood (3)	12.1	.33
Norway	Elec. Machinery/Equipment (85)	8.93	.33	Machinery, Mech. Appliances (84)	7.13	.29
Peru	Machinery, Mech. Appliances (84)	14.47	.30	Ores, Slag, and Ash (26)	29.75	.34
Peru	Elec. Machinery/Equipment (85)	11.76	.20	Precious Stones, Pearls (71)	17.19	.31
Peru	Mineral Fuels/Oils, etc. (27)	10.28	.59	Fruits and Nuts (8)	6.61	.29
ROW	Elec. Machinery/Equipment (85)	17.06	.16	Mineral Fuels/Oils, etc. (27)	22.38	.38
ROW	Machinery, Mech. Appliances (84)	13.34	.18	Elec. Machinery/Equipment (85)	14.34	.36
ROW	Vehicles (87)	7.49	.27	Machinery, Mech. Appliances (84)	7.92	.37
Rep. of Korea	Mineral Fuels/Oils, etc. (27)	23.69	.26	Elec. Machinery/Equipment (85)	30.78	.30
Rep. of Korea	Elec. Machinery/Equipment (85)	17.82	.29	Machinery, Mech. Appliances (84)	11.97	.28
Rep. of Korea	Machinery, Mech. Appliances (84)	10.64	.30	Vehicles (87)	11.32	.28
Romania	Elec. Machinery/Equipment (85)	15.42	.35	Elec. Machinery/Equipment (85)	18.05	.34
Romania	Machinery, Mech. Appliances (84)	13.18	.36	Vehicles (87)	14.12	.40
Romania	Vehicles (87)	8.71	.21	Machinery, Mech. Appliances (84)	10.39	.30
Russia	Machinery, Mech. Appliances (84)	18.99	.26	Mineral Fuels/Oils, etc. (27)	59.59	.48
Russia	Elec. Machinery/Equipment (85)	11.74	.18	Iron and Steel (72)	5.38	.56
Russia	Vehicles (87)	8.55	.28	Precious Stones, Pearls (71)	3.19	.41
Spain	Mineral Fuels/Oils, etc. (27)	13.9	.42	Vehicles (87)	18.53	.41
Spain	Vehicles (87)	12.75	.62	Machinery, Mech. Appliances (84)	8.23	.29
Spain	Machinery, Mech. Appliances (84)	9.57	.26	Elec. Machinery/Equipment (85)	5.76	.38
Sweden	Machinery, Mech. Appliances (84)	13.4	.20	Machinery, Mech. Appliances (84)	17.48	.31
Sweden	Elec. Machinery/Equipment (85)	13.19	.17	Vehicles (87)	12.59	.34
Sweden	Vehicles (87)	11.73	.39	Elec. Machinery/Equipment (85)	10.79	.34
USA	Elec. Machinery/Equipment (85)	14.98	.16	Machinery, Mech. Appliances (84)	15.39	.31
USA	Machinery, Mech. Appliances (84)	14.83	.19	Elec. Machinery/Equipment (85)	10.88	.30
USA	Vehicles (87)	12.78	.25	Vehicles (87)	8.84	.19
UK	Vehicles (87)	12.73	.62	Machinery, Mech. Appliances (84)	14.12	.35
UK	Machinery, Mech. Appliances (84)	12.32	.54	Vehicles (87)	12.67	.26
UK	Elec. Machinery/Equipment (85)	9.78	.55	Precious Stones, Pearls (71)	10.64	.34
Viet Nam	Elec. Machinery/Equipment (85)	25.43	.12	Elec. Machinery/Equipment (85)	32.41	.31
Viet Nam	Machinery, Mech. Appliances (84)	12.83	.18	Footwear (64)	8.43	.32
Viet Nam	Plastics and Articles thereof (39)	6.03	.29	Machinery, Mech. Appliances (84)	7.37	.28

Notes: Inverse demand elasticity in each HS2 sector is the average of HS4 inverse demand elasticites, weighted by trade volumes.

Table F.3: 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
Machinery, Mech. Appliances (84)	.541	13.32	.29	17.69	.246	7.9	.286	6.91
Elec. Machinery/Equipment (85)	.574	12.57	.325	9.73	.248	4.36	.363	3.27
Vehicles (87)	.293	9.96	.37	19.63	.278	11.61	.417	10.61
Mineral Fuels/Oils, etc. (27)	.297	6.64	.543	1.48	.43	12.18	.489	11.61
Pharmaceutical Products (30)	.815	4.58	.509	5.86	.112	9.92	.544	9.11
Plastics and Articles thereof (39)	.57	3.78	.401	4.67	.263	4.3	.396	7.79
Instruments/Apparatus (90)	.559	3.64	.407	4.87	.181	3.36	.464	2.55
Organic Chemicals (29)	.701	3.16	.459	2.31	.448	8.75	.534	5.96
Aircraft, Spacecraft (88)	.766	2.59	.358	3.04	.173	.25	.527	.32
Iron and Steel (72)	.414	2.43	.419	1.92	.308	2.67	.398	3.69
Iron and Steel Articles (73)	.43	1.95	.394	2.28	.385	1.22	.404	1.08
Furniture, Bedding, etc. (94)	.662	1.88	.228	1.16	.403	.94	.264	.54
Cloth. Accessories, knitted (61)	.386	1.72	.278	.46	.165	1.05	.363	.59
Cloth. Acc., not knitted (62)	.47	1.72	.352	.5	.173	.93	.375	.44
Aluminium & Articles thereof (76)	.318	1.62	.484	1.14	.287	.83	.377	.77
Precious Stones, Pearls (71)	.262	1.48	.483	.89	.376	4.68	.48	6.76
Rubber and Articles thereof (40)	.446	1.43	.281	1.17	.236	1.11	.311	1.15
Chemical Products, N.E.C. (38)	.445	1.33	.46	1.83	.372	1.47	.452	2.02
Paper, Paperboard (48)	.653	1.29	.521	1.47	.391	1.17	.549	1.07
Footwear (64)	.192	1.07	.309	.33	.11	.99	.357	.86
Weighted Average:	**0.482**		**0.378**		**0.309**		**0.433**	

Notes: Inverse demand elasticity in each HS2 sector is the average of HS4 inverse demand elasticites, weighted by trade volumes.

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

	China			
	Imports		Exports	
Product Category (HS2 level)	$1/\sigma$	Share	$1/\sigma$	Share
Machinery, Mech. Appliances (84)	.404	8.9	.249	17.26
Elec. Machinery/Equipment (85)	.382	21.8	.255	28.97
Vehicles (87)	.218	4.55	.378	2.54
Mineral Fuels/Oils, etc. (27)	.333	12.97	.583	.91
Pharmaceutical Products (30)	.348	1.26	.578	.25
Plastics and Articles thereof (39)	.246	4.14	.475	2.83
Instruments/Apparatus (90)	.3	5.68	.334	2.99
Organic Chemicals (29)	.267	3.12	.541	1.83
Aircraft, Spacecraft (88)	.279	1.69	.24	.09
Iron and Steel (72)	.344	1.17	.427	2.12
Iron and Steel Articles (73)	.347	.63	.383	2.63
Furniture, Bedding, etc. (94)	.349	.2	.217	3.82
Cloth. Accessories, knitted (61)	.29	.13	.31	3.2
Cloth. Accessories, not knitted (62)	.208	.21	.39	3.18
Aluminium and Articles thereof (76)	.108	.43	.513	.92
Precious Stones, Pearls (71)	.653	6.24	.353	1.24
Rubber and Articles thereof (40)	.326	.91	.211	.91
Chemical Products, N.E.C. (38)	.415	.93	.537	.58
Paper, Paperboard (48)	.404	.25	.47	.75
Footwear (64)	.466	.16	.343	2.39
Weighted Average:	**0.361**		**0.321**	

Notes: Inverse demand elasticity in each HS2 sector is the average of HS4 inverse demand elasticites, weighted by trade volumes.

Table F.5: 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
Machinery, Mech. Appliances (84)	.208	13.32	.207	17.69	.177	7.9	.18	6.91
Elec. Machinery/Equipment (85)	.183	12.57	.218	9.73	.218	4.36	.236	3.27
Vehicles (87)	.335	9.96	.245	19.63	.194	11.61	.21	10.61
Mineral Fuels/Oils, etc. (27)	.665	6.64	.651	1.48	.646	12.18	.645	11.61
Pharmaceutical Products (30)	.616	4.58	.617	5.86	.617	9.92	.616	9.11
Plastics and Articles thereof (39)	.441	3.78	.438	4.67	.395	4.3	.344	7.79
Instruments/Apparatus (90)	.334	3.64	.335	4.87	.445	3.36	.441	2.55
Organic Chemicals (29)	.608	3.16	.615	2.31	.58	8.75	.606	5.96
Aircraft, Spacecraft (88)	.093	2.59	.097	3.04	.088	.25	.071	.32
Iron and Steel (72)	.509	2.43	.507	1.92	.575	2.67	.56	3.69
Iron and Steel Articles (73)	.476	1.95	.441	2.28	.472	1.22	.421	1.08
Furniture, Bedding, etc. (94)	.127	1.88	.124	1.16	.125	.94	.152	.54
Cloth. Acc., not knitted (62)	.462	1.72	.462	.5	.47	.93	.507	.44
Cloth. Accessories, knitted (61)	.241	1.72	.237	.46	.245	1.05	.23	.59
Aluminium & Articles thereof (76)	.577	1.62	.603	1.14	.569	.83	.59	.77
Precious Stones, Pearls (71)	.311	1.48	.376	.89	.603	4.68	.588	6.76
Rubber and Articles thereof (40)	.214	1.43	.246	1.17	.237	1.11	.264	1.15
Chemical Products, N.E.C. (38)	.599	1.33	.617	1.83	.645	1.47	.667	2.02
Paper, Paperboard (48)	.601	1.29	.591	1.47	.589	1.17	.577	1.07
Footwear (64)	.272	1.07	.286	.33	.294	.99	.292	.86
Weighted Average:	**0.377**		**0.344**		**0.452**		**0.455**	

Notes: Inverse demand elasticity in each HS2 sector is the average of HS4 inverse demand elasticites, weighted by trade volumes. We assume all countries share the same demand elasticities as in the U.S.

Table F.6: 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
Machinery, Mech. Appliances (84)	.194	8.9	.13	17.26
Elec. Machinery/Equipment (85)	.11	21.8	.157	28.97
Vehicles (87)	.29	4.55	.465	2.54
Mineral Fuels/Oils, etc. (27)	.64	12.97	.66	.91
Pharmaceutical Products (30)	.616	1.26	.619	.25
Plastics and Articles thereof (39)	.336	4.14	.55	2.83
Instruments/Apparatus (90)	.263	5.68	.284	2.99
Organic Chemicals (29)	.431	3.12	.605	1.83
Aircraft, Spacecraft (88)	.104	1.69	.082	.09
Iron and Steel (72)	.545	1.17	.473	2.12
Iron and Steel Articles (73)	.466	.63	.423	2.63
Furniture, Bedding, etc. (94)	.13	.2	.119	3.82
Cloth. Accessories, not knitted (62)	.413	.21	.428	3.18
Cloth. Accessories, knitted (61)	.225	.13	.254	3.2
Aluminium and Articles thereof (76)	.603	.43	.635	.92
Precious Stones, Pearls (71)	.362	6.24	.336	1.24
Rubber and Articles thereof (40)	.324	.91	.143	.91
Chemical Products, N.E.C. (38)	.601	.93	.668	.58
Paper, Paperboard (48)	.632	.25	.536	.75
Footwear (64)	.24	.16	.331	2.39
Weighted Average:	**0.374**		**0.272**	

Notes: Inverse demand elasticity in each HS2 sector is the average of HS4 inverse demand elasticites, weighted by trade volumes. We assume all countries share the same demand elasticities as in the U.S.

Table F.7: A Global Tariff War (using CEPII 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	-0.124	-1.006	0.593	0.289	-1.374	-1.658	0.284
Austria	-1.994	-1.116	-1.614	0.736	-1.209	-1.948	0.739
Bangladesh	-0.162	-0.158	-0.015	0.011	-0.233	-0.244	0.011
Belgium	-7.163	-1.888	-6.224	0.949	-2.132	-3.124	0.993
Brazil	-0.780	-0.385	-0.248	-0.148	-0.788	-0.640	-0.148
Canada	-6.863	-2.165	-5.547	0.848	-2.093	-2.979	0.887
China	-0.370	-0.274	-0.246	0.150	-0.268	-0.418	0.150
Denmark	-4.469	-2.204	-3.627	1.362	-2.077	-3.463	1.386
France	-2.820	-1.156	-2.300	0.635	-1.146	-1.791	0.645
Germany	0.795	-0.910	1.156	0.550	-0.892	-1.434	0.542
Greece	-1.072	-0.363	-0.925	0.216	-0.377	-0.594	0.217
India	-0.494	-0.153	-0.332	-0.010	-0.219	-0.210	-0.009
Indonesia	-0.208	-0.751	0.294	0.250	-1.006	-1.253	0.247
Italy	0.215	-0.532	0.354	0.393	-0.472	-0.863	0.391
Japan	0.748	-0.142	0.789	0.102	-0.160	-0.261	0.101
Rep. of Korea	-0.324	-0.248	-0.155	0.079	-0.259	-0.338	0.079
Mexico	-1.139	-1.355	-0.542	0.757	-1.238	-1.998	0.760
Netherlands	-2.553	-1.203	-2.153	0.802	-1.312	-2.123	0.811
New Zealand	-1.796	-0.791	-1.483	0.478	-0.634	-1.117	0.482
Norway	-1.602	-1.144	-0.985	0.527	-1.359	-1.887	0.528
Peru	-0.204	-0.184	-0.084	0.063	-0.210	-0.273	0.064
Romania	-0.334	-0.498	-0.197	0.360	-0.450	-0.809	0.359
Russia	-1.174	-0.569	-0.708	0.103	-0.814	-0.918	0.103
Vietnam	-3.815	-1.291	-3.061	0.538	-1.265	-1.819	0.554
Spain	-0.620	-0.388	-0.474	0.241	-0.460	-0.701	0.241
Sweden	0.141	-0.438	0.138	0.441	-0.696	-1.135	0.439
Egypt	-0.226	-0.278	0.045	0.007	-0.492	-0.498	0.007
United Kingdom	1.657	-0.969	2.060	0.567	-1.243	-1.796	0.552
USA	-0.833	-0.313	-0.699	0.179	-0.427	-0.607	0.180
ROW	-1.364	-1.626	-0.727	0.989	-1.745	-2.711	0.967

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 (49), 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 F.8: 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	-0.499	-1.354	-0.730	1.585	-0.655	-2.238	1.583
Austria	-0.812	-1.623	-1.318	2.130	-0.701	-2.833	2.132
Bangladesh	-0.157	-0.282	-0.124	0.249	-0.184	-0.433	0.249
Belgium	-3.183	-3.199	-3.763	3.779	-1.496	-5.324	3.829
Brazil	-0.406	-0.667	-0.369	0.629	-0.478	-1.108	0.629
Canada	-3.945	-3.191	-3.825	3.070	-1.350	-4.483	3.132
China	-0.259	-0.602	-0.333	0.675	-0.241	-0.917	0.676
Denmark	-2.241	-3.197	-2.676	3.632	-1.394	-5.046	3.652
France	-1.430	-1.802	-1.771	2.143	-0.645	-2.804	2.158
Germany	-0.151	-1.433	-0.406	1.689	-0.575	-2.258	1.683
Greece	-0.599	-0.571	-0.767	0.739	-0.198	-0.940	0.742
India	-0.287	-0.281	-0.270	0.263	-0.122	-0.386	0.264
Indonesia	-0.095	-1.118	-0.269	1.292	-0.570	-1.859	1.288
Italy	-0.002	-0.913	-0.247	1.159	-0.320	-1.477	1.157
Japan	0.244	-0.250	0.131	0.363	-0.095	-0.458	0.363
Rep. of Korea	-0.287	-0.454	-0.295	0.462	-0.157	-0.619	0.463
Mexico	-0.775	-1.973	-0.884	2.082	-0.822	-2.909	2.087
Netherlands	-1.190	-1.827	-1.745	2.382	-0.837	-3.227	2.390
New Zealand	-1.042	-1.265	-1.114	1.338	-0.445	-1.790	1.345
Norway	-0.956	-1.670	-1.257	1.972	-0.793	-2.766	1.972
Peru	-0.136	-0.247	-0.167	0.278	-0.088	-0.366	0.278
Romania	-0.224	-0.748	-0.424	0.947	-0.268	-1.215	0.947
Russia	-0.728	-0.835	-0.793	0.900	-0.447	-1.349	0.902
Vietnam	-2.241	-2.091	-2.153	2.003	-0.936	-2.963	2.027
Spain	-0.215	-0.596	-0.449	0.830	-0.247	-1.077	0.830
Sweden	1.380	-0.647	0.722	1.305	-0.359	-1.651	1.292
Egypt	-0.022	-0.337	-0.091	0.406	-0.198	-0.603	0.405
United Kingdom	0.516	-1.424	-0.073	2.013	-0.619	-2.616	1.997
USA	-0.167	-0.436	-0.401	0.670	-0.171	-0.840	0.669
ROW	-0.975	-2.328	-1.550	2.904	-0.981	-3.883	2.902

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 (49), 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 2.13, which is the median trade elasticities that we estimated in Section 5. Numbers are rounded to the nearest thousandth.

Table F.9: A Global Tariff War (Homogeneous Substitution Elasticities and $\theta = \sigma - 1$): 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	-2.641	-0.406	-3.701	1.466	0.782	-0.707	1.489
Austria	-1.989	-1.145	-2.396	1.552	-0.820	-2.388	1.568
Bangladesh	-0.105	-0.262	-0.105	0.262	-0.387	-0.648	0.261
Belgium	-3.558	-2.681	-4.169	3.292	-2.050	-5.371	3.321
Brazil	-1.857	-0.260	-2.061	0.464	-0.013	-0.492	0.479
Canada	-3.660	-1.824	-4.218	2.382	-0.667	-3.103	2.437
China	-0.837	-0.334	-0.900	0.397	-0.323	-0.728	0.405
Denmark	-3.705	-2.414	-3.987	2.696	-1.354	-4.107	2.753
France	-2.099	-1.462	-2.249	1.612	-0.970	-2.598	1.628
Germany	-1.849	-0.800	-2.198	1.148	-0.547	-1.732	1.185
Greece	-0.205	-0.732	-0.303	0.830	-0.593	-1.419	0.826
India	-0.037	-0.237	-0.061	0.260	-0.310	-0.570	0.260
Indonesia	-2.014	-0.596	-2.519	1.101	-0.178	-1.307	1.128
Italy	-0.901	-0.679	-1.115	0.892	-0.526	-1.429	0.903
Japan	-0.240	-0.246	-0.257	0.263	-0.240	-0.504	0.263
Rep. of Korea	-0.342	-0.245	-0.416	0.319	-0.243	-0.565	0.322
Mexico	-2.160	-1.381	-2.161	1.382	-1.069	-2.469	1.400
Netherlands	-2.452	-1.235	-3.125	1.907	-0.586	-2.541	1.955
New Zealand	-1.430	-0.843	-1.606	1.020	-0.249	-1.280	1.032
Norway	-2.443	-0.626	-4.075	2.258	1.239	-1.083	2.322
Peru	-0.397	-0.150	-0.499	0.252	0.041	-0.212	0.253
Romania	-0.894	-0.649	-0.964	0.719	-0.530	-1.252	0.722
Russia	-2.064	-0.202	-3.002	1.140	0.851	-0.332	1.183
Vietnam	-2.150	-1.344	-2.036	1.230	-1.284	-2.532	1.248
Spain	-0.423	-0.520	-0.575	0.672	-0.557	-1.228	0.671
Sweden	-1.393	-0.605	-1.776	0.988	-0.362	-1.366	1.004
Egypt	-0.203	-0.653	-0.008	0.457	-0.695	-1.149	0.454
United Kingdom	-1.860	-1.779	-1.508	1.426	-1.422	-2.850	1.428
USA	-0.579	-0.483	-0.579	0.483	-0.440	-0.922	0.482
ROW	-2.987	-1.696	-3.473	2.181	-0.564	-2.889	2.326

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 (49), 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 that all countries share the same elasticities of substitution as in the U.S., and that trade elasticities θ are equal to $\sigma - 1$. Numbers are rounded to the nearest thousandth.

Table F.10: 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	-0.112	-0.071	-0.044	0.003	-0.115	-0.118	0.003
Austria	-0.037	-0.040	0.005	-0.002	-0.071	-0.069	-0.002
Bangladesh	-0.022	-0.010	-0.009	-0.003	-0.018	-0.015	-0.003
Belgium	-0.347	-0.134	-0.202	-0.011	-0.238	-0.227	-0.011
Brazil	-0.141	-0.059	-0.066	-0.017	-0.115	-0.098	-0.017
Canada	-2.457	-1.165	-1.262	-0.030	-1.664	-1.636	-0.028
China	-0.025	-0.046	0.028	-0.007	-0.076	-0.069	-0.007
Denmark	-0.145	-0.078	-0.062	-0.005	-0.129	-0.124	-0.005
France	-0.100	-0.076	-0.020	-0.005	-0.122	-0.117	-0.005
Germany	-0.042	-0.062	0.023	-0.004	-0.101	-0.097	-0.004
Greece	-0.011	-0.008	-0.002	-0.000	-0.014	-0.014	-0.000
India	-0.026	-0.015	-0.008	-0.004	-0.024	-0.020	-0.004
Indonesia	-0.032	-0.043	0.018	-0.007	-0.079	-0.072	-0.007
Italy	-0.013	-0.028	0.016	-0.002	-0.046	-0.045	-0.002
Japan	0.003	-0.019	0.025	-0.002	-0.038	-0.035	-0.002
Rep. of Korea	-0.032	-0.029	-0.001	-0.003	-0.042	-0.040	-0.003
Mexico	-0.985	-0.709	-0.275	-0.000	-1.047	-1.047	-0.000
Netherlands	-0.121	-0.062	-0.054	-0.005	-0.116	-0.111	-0.005
New Zealand	-0.174	-0.089	-0.079	-0.005	-0.132	-0.127	-0.005
Norway	-0.107	-0.051	-0.055	-0.001	-0.087	-0.086	-0.001
Peru	-0.039	-0.027	-0.011	-0.001	-0.042	-0.041	-0.001
Romania	-0.001	-0.005	0.004	-0.000	-0.008	-0.008	-0.000
Russia	-0.066	-0.027	-0.034	-0.005	-0.050	-0.045	-0.005
Vietnam	-0.112	-0.104	-0.002	-0.007	-0.151	-0.145	-0.007
Spain	-0.031	-0.014	-0.015	-0.001	-0.027	-0.027	-0.001
Sweden	-0.006	-0.014	0.009	-0.001	-0.037	-0.035	-0.001
Egypt	-0.024	-0.011	-0.011	-0.003	-0.022	-0.020	-0.003
United Kingdom	-0.038	-0.080	0.047	-0.005	-0.151	-0.146	-0.006
USA	0.406	-0.231	-0.150	0.787	0.339	-0.447	0.786
ROW	-0.256	-0.149	-0.097	-0.009	-0.260	-0.250	-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 (49), 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 F.11: 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	0.052	-1.332	-0.117	1.502	-0.630	-2.125	1.495
Austria	-1.196	-1.324	-1.781	1.909	-0.888	-2.802	1.914
Bangladesh	-0.307	-0.268	-0.244	0.206	-0.143	-0.350	0.207
Belgium	-3.976	-3.674	-3.760	3.458	-1.677	-5.205	3.528
Brazil	-0.116	-0.606	-0.062	0.552	-0.494	-1.045	0.551
Canada	-4.455	-3.397	-3.928	2.869	-1.629	-4.565	2.935
China	-0.081	-0.603	-0.052	0.573	-0.264	-0.837	0.573
Denmark	-1.504	-3.214	-1.711	3.421	-1.425	-4.853	3.428
France	-1.244	-1.889	-1.350	1.996	-0.758	-2.766	2.007
Germany	-0.227	-1.479	-0.320	1.572	-0.547	-2.116	1.569
Greece	0.075	-0.574	-0.049	0.699	-0.328	-1.025	0.697
India	-0.198	-0.297	-0.113	0.212	-0.162	-0.375	0.213
Indonesia	0.052	-1.064	-0.062	1.178	-0.509	-1.685	1.175
Italy	0.809	-0.797	0.537	1.069	-0.322	-1.385	1.063
Japan	0.276	-0.282	0.227	0.332	-0.111	-0.442	0.331
Rep. of Korea	-0.431	-0.431	-0.401	0.401	-0.200	-0.602	0.402
Mexico	-0.816	-1.970	-0.745	1.899	-0.756	-2.661	1.904
Netherlands	-1.731	-2.179	-1.751	2.199	-0.892	-3.108	2.216
New Zealand	-1.332	-1.476	-1.081	1.226	-0.803	-2.035	1.232
Norway	-0.660	-1.848	-0.670	1.858	-0.772	-2.631	1.859
Peru	-0.048	-0.241	-0.066	0.259	-0.085	-0.344	0.259
Romania	-0.434	-0.757	-0.529	0.852	-0.328	-1.182	0.854
Russia	0.457	-0.717	0.341	0.832	-0.448	-1.277	0.829
Vietnam	-2.591	-1.968	-2.317	1.694	-1.040	-2.761	1.721
Spain	-0.301	-0.634	-0.449	0.782	-0.281	-1.063	0.783
Sweden	-1.175	-1.482	-0.878	1.185	-0.509	-1.701	1.192
Egypt	-0.266	-0.406	-0.229	0.369	-0.319	-0.687	0.369
United Kingdom	-0.035	-1.547	-0.347	1.860	-0.819	-2.668	1.850
USA	-0.264	-0.493	-0.386	0.615	-0.250	-0.865	0.616
ROW	-1.861	-2.517	-1.912	2.567	-1.060	-3.684	2.625

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 (49), 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 D. Numbers are rounded to the nearest thousandth.

Table F.12: Tariffs, Inverse Elasticities and Import/Export Shares for the U.S.-China Trade War

Product Category (HS2 level)	U.S. Share	U.S. $1/\sigma_{Im}$	U.S. $1/\sigma_{Ex}$	U.S. Tariff	China Share	China $1/\sigma_{Im}$	China $1/\sigma_{Ex}$	China Tariff
Elec. Machinery/Equipment (85)	27.31	.162	.37	13.5119	13.14	.37	.162	9.22
Machinery, Mech. Appliances (84)	21.49	.126	.365	13.83844	10.69	.365	.126	11.84
Furniture, Bedding, etc. (94)	6.19	.115	.467	20.15539	.26	.467	.115	17.65
Toys, Games, etc. (95)	5.17	.014	.743	2.901873	.1	.743	.014	14.01
Footwear (64)	3.61	.309	.588	8.462082	.06	.588	.309	19.52
Cloth. Accessories, knitted (61)	3.4	.279	.311	13.28404	.01	.311	.279	25.17
Plastics and Articles thereof (39)	3.1	.592	.275	15.16546	4.24	.275	.592	13.08
Cloth. Accessories, not knitted (62)	3.08	.448	.25	14.37621	.01	.25	.448	24.67
Vehicles (87)	2.79	.593	.169	23.72763	8.88	.169	.593	31.86
Instruments/Apparatus (90)	2.29	.278	.47	16.50305	7.61	.47	.278	11.58
Iron and Steel Articles (73)	2.28	.441	.347	20.12378	.8	.347	.441	19.84
Articles of Leather (42)	1.84	.076	.336	24.99968	.01	.336	.076	26.21
Textiles, made up articles, rags (63)	1.64	.526	.431	10.12286	.02	.431	.526	23.43
Organic Chemicals (29)	1.39	.618	.292	10.53818	2.13	.292	.618	15.75
Metal, miscellaneous products (83)	1.02	.594	.362	19.13247	.11	.362	.594	19.54
Rubber and Articles thereof (40)	.95	.146	.265	24.2285	.77	.265	.146	13.37
Wood and Articles of Wood (44)	.88	.337	.378	21.37629	1.49	.378	.337	21.28
Tools, Cutlery, etc. (82)	.77	.279	.323	20.65189	.19	.323	.279	20.65
Precious Stones, Pearls (71)	.67	.24	.664	10.01166	4.05	.664	.240	20.15
Paper, Paperboard (48)	.66	.481	.402	24.17612	.61	.402	.481	14.11

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

Table F.13: 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	-0.000	-0.002	0.002	0.000	-0.004	-0.004	0.000
Austria	-0.000	0.002	-0.003	0.000	0.004	0.004	0.000
Bangladesh	0.002	0.001	0.000	0.001	0.002	0.001	0.001
Belgium	0.003	0.000	0.002	0.000	0.001	0.001	0.000
Brazil	0.003	0.000	0.002	0.001	0.001	0.001	0.001
Canada	0.009	0.012	-0.004	0.001	0.018	0.017	0.001
China	0.024	-0.084	0.050	0.058	-0.068	-0.127	0.058
Denmark	0.007	0.004	0.002	0.001	0.007	0.006	0.001
France	0.007	0.004	0.002	0.001	0.007	0.007	0.001
Germany	0.004	0.003	0.000	0.000	0.005	0.005	0.000
Greece	0.001	0.001	0.000	0.000	0.001	0.001	0.000
India	0.001	0.001	0.001	0.000	0.001	0.001	0.000
Indonesia	0.001	0.003	-0.001	-0.000	0.004	0.004	-0.000
Italy	0.001	0.001	-0.001	0.000	0.002	0.002	0.000
Japan	-0.001	0.001	-0.002	0.000	0.002	0.002	0.000
Rep. of Korea	0.002	0.002	-0.000	0.000	0.002	0.002	0.000
Mexico	0.016	0.020	-0.006	0.001	0.031	0.030	0.001
Netherlands	0.005	0.002	0.003	0.000	0.003	0.003	0.000
New Zealand	-0.001	-0.002	0.001	-0.000	-0.003	-0.002	-0.000
Norway	0.002	0.002	0.000	0.000	0.003	0.003	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	0.001	0.000
Russia	0.004	0.000	0.004	-0.000	0.000	0.001	-0.000
Vietnam	0.013	0.010	0.002	0.001	0.014	0.014	0.001
Spain	0.002	0.001	0.001	0.000	0.001	0.001	0.000
Sweden	0.000	0.001	-0.001	0.000	0.002	0.002	0.000
Egypt	0.000	0.000	0.000	0.000	0.001	0.000	0.000
United Kingdom	0.003	0.003	-0.000	0.000	0.005	0.005	0.000
USA	-0.092	-0.081	-0.121	0.110	-0.047	-0.157	0.109
ROW	0.011	0.007	0.003	0.001	0.012	0.011	0.001

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 (49), 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 F.14: 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	-0.007	-0.001	-0.006	0.000	-0.003	-0.003	0.000
Austria	-0.002	0.001	-0.003	0.000	0.002	0.002	0.000
Bangladesh	0.002	0.000	0.001	0.000	0.001	0.001	0.000
Belgium	0.003	0.000	0.003	0.000	0.001	0.001	0.000
Brazil	0.002	0.001	0.000	0.001	0.002	0.001	0.001
Canada	0.007	0.008	-0.001	0.001	0.015	0.014	0.001
China	0.060	-0.045	0.065	0.040	-0.057	-0.098	0.041
Denmark	0.002	0.002	-0.000	0.000	0.004	0.003	0.000
France	0.005	0.001	0.003	0.000	0.002	0.002	0.000
Germany	0.001	0.001	-0.000	0.000	0.002	0.002	0.000
Greece	0.001	0.000	0.001	0.000	0.001	0.001	0.000
India	0.001	0.000	0.001	0.000	0.001	0.001	0.000
Indonesia	0.000	0.001	-0.001	-0.000	0.003	0.003	-0.000
Italy	0.002	0.000	0.001	0.000	0.001	0.001	0.000
Japan	0.001	0.001	-0.000	0.000	0.002	0.001	0.000
Rep. of Korea	-0.001	0.001	-0.002	0.000	0.003	0.002	0.000
Mexico	0.002	0.011	-0.011	0.001	0.022	0.021	0.001
Netherlands	0.003	0.001	0.003	0.000	0.001	0.001	0.000
New Zealand	-0.001	-0.000	-0.000	-0.000	-0.001	-0.001	-0.000
Norway	0.001	0.000	0.000	0.000	0.001	0.001	0.000
Peru	-0.001	0.000	-0.001	0.000	0.000	0.000	0.000
Romania	0.001	0.000	0.001	0.000	0.001	0.001	0.000
Russia	0.001	0.001	0.001	-0.000	0.001	0.001	-0.000
Vietnam	0.006	0.006	-0.000	0.000	0.011	0.010	0.000
Spain	0.001	0.000	0.001	0.000	0.001	0.001	0.000
Sweden	-0.000	0.000	-0.001	0.000	0.001	0.001	0.000
Egypt	-0.000	0.000	-0.001	0.000	0.000	0.000	0.000
United Kingdom	0.006	0.002	0.004	0.000	0.003	0.003	0.000
USA	-0.105	-0.058	-0.129	0.082	-0.032	-0.113	0.081
ROW	0.003	0.006	-0.003	0.000	0.009	0.009	0.001

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 (49), 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 F.15: 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	0.011	0.006	0.005	-0.000	0.011	0.011	-0.000
Austria	0.002	0.000	0.002	-0.000	0.001	0.001	-0.000
Bangladesh	-0.001	-0.001	-0.000	-0.000	-0.001	-0.001	-0.000
Belgium	0.008	0.005	0.004	0.000	0.008	0.008	0.000
Brazil	0.005	0.003	0.001	0.001	0.006	0.005	0.001
Canada	0.021	0.013	0.009	-0.001	0.018	0.019	-0.001
China	-0.055	-0.046	-0.054	0.044	-0.025	-0.070	0.044
Denmark	-0.003	-0.000	-0.003	-0.000	-0.001	-0.000	-0.000
France	0.001	0.001	-0.000	-0.000	0.002	0.002	-0.000
Germany	0.002	0.002	0.001	-0.000	0.003	0.003	-0.000
Greece	-0.001	-0.000	-0.001	-0.000	-0.001	-0.001	-0.000
India	-0.001	-0.000	-0.001	0.000	-0.000	-0.000	0.000
Indonesia	0.001	0.001	-0.000	0.000	0.002	0.001	0.000
Italy	0.000	-0.000	0.001	-0.000	-0.000	-0.000	-0.000
Japan	0.002	0.001	0.001	0.000	0.002	0.001	0.000
Rep. of Korea	0.003	0.002	0.001	0.000	0.003	0.003	0.000
Mexico	0.000	-0.001	0.002	-0.001	-0.002	-0.001	-0.001
Netherlands	0.001	0.002	-0.001	-0.000	0.003	0.003	-0.000
New Zealand	0.010	0.006	0.004	0.000	0.008	0.008	0.000
Norway	0.002	0.002	-0.000	-0.000	0.003	0.003	-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	-0.002	0.001	-0.003	0.000	0.002	0.002	0.000
Vietnam	0.009	-0.002	0.011	-0.000	-0.003	-0.003	-0.000
Spain	-0.000	0.000	-0.000	-0.000	0.000	0.000	-0.000
Sweden	0.002	0.000	0.002	-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	-0.001	0.001	-0.002	-0.000	0.002	0.002	-0.000
USA	-0.060	-0.044	-0.048	0.032	-0.053	-0.085	0.032
ROW	0.002	0.005	-0.003	-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 (49), 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.