TARIFF REDUCTIONS, ENTRY, AND WELFARE:
THEORY AND EVIDENCE FOR THE LAST TWO DECADES

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ABSTRACT

Tariffs have fallen significantly around the globe over the last two decades. Yet very little is known about the trade, entry, and welfare effects generated by this unprecedented shift in trade policy. We use a heterogeneous-firm quantitative trade model to study the effects of observed changes in trade policy. Importantly, in our model, tariffs affect the entry decision of firms across markets, a channel that has been unduly overlooked in the literature. We first show how trade policy influences entry and selection of firms into markets. We then use a new tariff dataset, and apply a 189-country, 15-sector version of our model, to quantify the trade, entry, and welfare effects of trade liberalization over the period 1990–2010. We find that the impact on firm entry was larger in Advanced relative to Emerging markets; that more than 90% of the gains from trade are a consequence of the reductions in MFN tariffs (the Uruguay Round); that PTAs have not contributed much to the overall gains from trade; and that, with the exception of a few Emerging and Developing countries, most countries do not gain much (and some lose) from a move to complete free trade under zero tariffs.

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1 Introduction

After six postwar decades of relentless progress, in recent years world trade growth, and world trade liberalization, have both now seemingly ground to halt. Globally, trade grew twice as fast as GDP in the 25 years prior to 2007, but at a rate below GDP since late 2011. The multilateral rounds of tariff negotiations under the World Trade Organization (WTO) have stalled, possibly to the point of no return, and the 2001 Doha Round—hailed as a "development round" but concluded with a few face-saving proposals—failed in its primary goal of lowering tariffs for developing countries. With trade growth stagnant, little to show for a decade of WTO talks, and substantial roadblocks even standing in the way of smaller-scale deals like TPP and TTIP, should we conclude that tariff liberalization aimed at furthering gains from trade has largely run its course, and compared to the past has much less of a role to play in the world today?

We will argue that the answer could be yes for most, if not all, countries. To make this case convincingly, however, we need to extend the leading current trade models, and we need to take the application and calibration of these models to a global level using data of a scope not seen before.

From a theoretical perspective, we not only build upon the most up-to-date model in international trade—with heterogeneous firms in the tradition of Melitz (2003) and Chaney (2008)—but also extend this model to incorporate tariffs and the kind of input-output structure that is realistic for modern economies, following Caliendo and Parro (CP, 2015). With these more general model foundations, we find that firm entry decisions can have meaningful impacts on trade and welfare, in ways not captured hitherto in many current-generation trade models.[1]

From an empirical perspective, we then go well beyond recent quantitative exercises in expanding the data universe to build a tariff dataset that includes not just the usual sample of Advanced (e.g., OECD) economies, but also a large subsample of Emerging and Developing economies, using newly collected data going back to the 1980s.[2] Our work therefore permits a broader and more realistic

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[1]The importance of the input-output structure has been made clear in recent work by Costinot and Rodríguez-Clare (2014). They used stylized, uniform tariff cuts to show how the gains from trade are systematically larger when the input-output structure is taken into account. Here are echoes of an earlier trade literature on distortions due to high effective rates of protection, and more recent empirical trade and growth papers highlighting the damaging effects of tariffs on inputs (Goldberg et al. 2010; Estevadeordal and Taylor 2013).

[2]We unify tariff schedules from five different sources. With more than 1 million observations per year in the 1980s, rising to 2 million by the 2000s, with our tariff data we can perform tariff policy experiments which could not be explored before now.

computation of the retrospective, and prospective, gains from trade liberalization in both rich and poor nations, a step we think is crucial since it is in the poorer countries that trade liberalization has proceeded most rapidly since 1990, and in which there yet may be still significant scope for further tariff reductions.

To sum up, our paper develops new theoretical results about tariffs, and their effects on trade, entry, and welfare; it builds a new tariff dataset, uses data from high- and low-income countries to calibrate the model; and it uses the model to perform policy experiments to evaluate the gains from actual past trade liberalization and possible future gains yet to be realized.

We implement three policy experiments. First, we quantify the effects for 189 countries and 15 sectors of, allegedly, the most successful GATT/WTO process, the Uruguay Round.[3] We do so by evaluating the economic effects of the observed change in Most Favored Nations (MFN) tariffs for countries at the product level from the year 1990 to 2010. We then go beyond Uruguay Round and evaluate the impact of all observed changes in tariffs, namely MFN and preferential tariffs, during the same period. With this, we evaluate the effects of what we refer to Uruguay Round + Preference. Finally, we ask if there are any further gains in the world today by zeroing all tariffs, what we refer as Free Trade.

We find that the Uruguay Round had a profound impact. Almost all of the gains from tariff elimination result from the Uruguay Round. We find the effects from additional tariff reductions, namely PTAs, have not contributed much to total world trade and welfare. In fact, as a result of PTAs relative to MFN we find, on average, a tiny increase on average trade share (measured as imports to income ratio), whereas on its own the Uruguay Round doubled this average share. In terms of welfare, Uruguay Round generated an average increase in welfare of 5.6% while the additional effect in welfare from PTAs is 0.3%.

When looking at countries by income group, we find that both the Advanced and the Emerging and Developing economies gained most from Uruguay Round tariff elimination relative to PTAs. We also find that the distribution of gains across these two groups are quite different. For the Advanced economies, most countries gain and the gains do not vary widely. However, for Emerging and Developing economies, not all countries win, but the ones that do gain substantially.

We also go beyond trade and welfare effects and evaluate how commercial

[3]Bagwell and Staiger (2010) survey recent economic research on trade agreements, with special focus on the GATT/WTO. For earlier research on the impact of trade agreements, see, inter alia, Anderson and van Wincoop (2002), Baier and Bergstrand (2007; 2009), Deardorff (1998), Redding and Venables (2004), Rose (2004), Subramanian and Wei (2007), Trefler (1993; 2006).

policy has affected the entry and exit of firms across markets. We find that tariffs affect firm entry in very different ways across countries. For instance, the reductions in tariffs as a consequence of the Uruguay Round generated considerable changes in entry and exit of firms across industries in Advanced economies, while there was a much smaller effect on Emerging economies. This differential effect on entry, driven by international trade, is one of the reasons which may explain why welfare effects can vary so much across income groups.

The results are striking when we consider moving to a world without tariffs. Our results show that there may be extra gains for some Emerging economies. This is a very different picture compared to the case of Advanced economies where, according to our calculations, they appear not to gain much more from moving to a world with no tariffs. Therefore, our results indicate that the Uruguay Round of negotiation accomplished an awful lot for the Advanced economies, with gains left on the table mainly for the Emerging and Developing economies.

The remainder of the paper is structured as follows. In Section 2 we briefly recap the current generation of trade models, their treatment of tariffs and entry, and how these relate to gains from trade; then, introducing the main departures we take in this paper, we stress the critical role played by assumptions on tariff structures, iceberg versus tariff frictions, input-output structure, and the possibility of firm entry (that is, as distinct from firm selection). In Section 3, we present the quantitative model. In Section 4, to develop intuition, we present some key results with the aid of a simplified two-sector symmetric model. Section 5 describes the new tariff dataset and the rest of the data sources that we use in order to calibrate the 189 countries, 15 sector version of the model. Section 6 explains how we take the model to the data, and section 7 presents the empirical results which quantify the gains from tariff liberalization in the last 20 years, and the potential remaining gains from tariff liberalization going forward. Section 8 concludes.

2 Tariffs, Icebergs, Entry, and Welfare

The recent work of Melitz and Redding (2015) shows how, in a Melitz (2003) model, after relaxing the assumption of a Pareto distribution of firm productivities assumed in Chaney (2008), changes in iceberg trade cost impact entry and welfare. A major contribution of this paper is to clearly explain how *tariffs* affect entry, and ultimately welfare, in a Melitz (2003) model, even without relaxing the maintained assumption of a Pareto distribution of firm productivities.

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We believe that the potential for tariffs to impact entry has been largely overlooked in the literature. One reason for this is that iceberg transport costs do not affect entry in a Melitz-Chaney model, as shown most clearly by Arkolakis, Costinot, and Rodríguez-Clare (ACR, 2012). One of their "macro" assumptions—which they label R2—is that aggregate profits in any country i (Π_i, measured gross of the entry fee) are a constant share of aggregate revenue (R_i), and that assumption is indeed satisfied in the special case of a Pareto distribution on productivity draws. In the further special case of a symmetric, one-sector, one-factor model, revenue equals the factor supply (L_i), since without loss of generality we can normalize wages $w_i = 1$. In turn, revenue is fixed, aggregate profits are also fixed, and since these equal the number of entrants N times the fixed costs of entry f_i^E, it follows that $N_i = \Pi_i / f_i^E \propto R_i / f_i^E = L_i / f_i^E$, which in turn is also then fixed. Therefore, changes in iceberg transport costs have no impact on entry in this case.[4]

The first paper to introduce *ad valorem* tariffs into a Melitz-Chaney model that we are aware of is the important contribution of Balistreri, Hillberry, and Rutherford (2011). They note that entry is no longer necessarily fixed when either (i) *ad valorem* "revenue" tariffs are imposed rather than iceberg transport costs, or (ii) there are multiple sectors. Their quantitative model is based on GTAP and models the heterogeneous-firm sector as a single, aggregate manufacturing sector, with additional constant-returns sectors in the economy. Our approach makes further advances in several respects. We use a similarly simplified structure to analytically solve for the impact of *ad valorem* tariffs on entry in a 2-country symmetric version of our model, while in our more general quantitative model we use multiple heterogeneous-firm sectors. In addition, our tariff data are much more detailed than Balistreri et al. (2011), who consider a 50% tariff cut rather than the actual impact of the Uruguay Round.[5]

Two more recent contributions have also sought to consider *ad valorem* tariffs as opposed to iceberg transport costs in a Melitz-Chaney model: these are the works by Felbermayr, Jung, and Larch (FJL, 2013, revised 2015) and Costinot and Rodríguez-Clare (CR, 2014).[6] In a working paper, FJL (2013) focus on a one-

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[4]In a multi-sector model, however, the factor supply to each sector is not fixed so it is quite possible that changes in iceberg transport costs will affect entry, as ACR (section IV.A) note.

[5]Another difference is that Balistreri et al. (2011) estimate all the fixed costs in their model from GTAP data. In contrast, we use the "hat" algebra (Dekle, Eaton, and Kortum 2008) to solve for changes in the key variables, which avoids the need to estimate fixed costs.

[6]Contemporaneous work continues on this theme. Bagwell and Lee (2015) consider tariffs and entry in the Melitz-Ottaviano (2008) model. Hsieh et al. (2015), adopt a Melitz and Redding (2015)

sector model with the *ad valorem* tariffs modeled as "revenue tariffs"—meaning that the taxes are applied to full import revenue (covering all production costs, fixed and variable, and profits, and hence fully inclusive of markups). In contrast, CR focus in their main text on the case of *ad valorem* tariffs as so-called "cost tariffs"—meaning that taxed are assumed only to the variable production costs of imports (without the markup, and without fixed costs or profits).[7] CR also introduce multiple sectors and traded intermediate inputs. Both papers allow for only a fraction (including zero or one) of tariff revenue to be rebated to consumers. Building on CR's treatment, the in-press version of FJL (2015) allows for both revenue tariffs and cost tariffs within a one-sector version of the Melitz-Chaney model, and then uses CR's multi-sector quantitative model in their simulations. Naturally, the reader may worry that cost tariffs are less appealing as a description of reality, and arguably no more tractable, an issue we will return to.

In their working paper, FJL (2013) are clear that they believe assumption R2 continues to hold in a one-sector model, while using revenue tariffs with fractional rebate. As a result, they argue, entry is fixed. In the in-press version, FJL (2015) do not explicitly refer to R2, but make the stronger claim that entry is fixed with *either* cost or revenue tariffs and regardless of the rebate: "there are no entry effects associated with changes in iceberg costs and tariffs as innovation fixed costs are assumed to arise in terms of domestic labor" (p. 6). We believe that the impact of tariffs on entry in the one-sector model is much more subtle than recognized by FJL (2015), as we now explain (with full details given in Appendix A).

Consider first the case of cost tariffs, with no rebate to consumers. The government instead wastes the tariff revenue. Assume labor in country i is the numeraire, with $w_i = 1$. Using a tilde to denote the consumer price—inclusive of freight and tariffs (if any)—and the corresponding consumer quantity, the firm in country i selling to country j solves the profit-maximization problem

$$\pi_{ij}(\varphi) = \max_{\tilde{p}_{ij}(\varphi) \geq 0} \left\{ \tilde{p}_{ij}(\varphi) \tilde{q}_{ij}(\varphi) - \frac{\tau_{ij}(1 + t_{ij})\tilde{q}_{ij}(\varphi)}{\varphi} - f_{ij} \right\}, \qquad (1)$$

where $\tilde{q}_{ij}(\varphi)$ is the quantity chosen by consumers at the price $\tilde{p}_{ij}(\varphi)$, the firm's marginal costs inclusive of iceberg costs τ_{ij} and the *ad valorem* cost tariff t_{ij} are $\tau_{ij}(1 + t_{ij})/\varphi$, and f_{ij} are the fixed operating costs. We assume CES demand with

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iceberg structure, and empirically examine the selection effect on firms due to the Canada-U.S. free trade agreement, which occurred just prior to our sample period.

   [7]The case of *ad valorem* tariffs as revenue tariffs is briefly discussed in the online Appendix to CR, who refer to these two types of tariffs as "cost-shifters" and "demand-shifters."

elasticity σ and a Pareto distribution, $G(\varphi) = 1 - \varphi^{-\theta}$, for the firm productivities, with $\varphi \geq 1$. Then it can be shown by evaluating the integrals below that assumption R2 of ACR holds, namely:

$$\underbrace{\int_{\varphi_{ij}^*}^{\infty} \pi_{ij}(\varphi) \, dG(\varphi)}_{\Pi_{ij} \equiv \text{ profits from } j} = \frac{\sigma - 1}{\sigma \theta} \underbrace{\int_{\varphi_{ij}^*}^{\infty} \tilde{p}_{ij}(\varphi) \, \tilde{q}_{ij}(\varphi) \, dG(\varphi)}_{\widetilde{R}_{ij} \equiv \text{ revenue paid by consumers in } j} , \qquad (2)$$

where φ_{ij}^* is the zero cutoff profit level of productivity at which $\pi_{ij}(\varphi_{ij}^*) = 0$. Now, summing over all destination markets j, denoting the mass of entrants by N_i and the sunk costs of entry by f_i^E, and using the free-entry condition and equation (2), our Appendix A shows that it is straightforward to obtain $N_i f_i^E = \Pi_i = \frac{\sigma-1}{\sigma\theta}\widetilde{R}_i = \left(\frac{\sigma-1}{\sigma\theta}\right) L_i$, where L_i is the labor earnings in this one-sector economy coming from the aggregate revenue of firms. It immediately follows that entry

$$N_i = \left(\frac{\sigma - 1}{\sigma \theta}\right) \frac{1}{f_i^E} L_i \qquad (3)$$

is fixed and does not vary with iceberg trade costs or with unrebated cost tariffs.

In comparison, now consider the case of revenue tariffs with *full* rebate of the tariff to consumers. In this case, the tariff-inclusive price $\tilde{p}_{ij}(\varphi)$ must be divided by $(1 + t_{ij})$ to obtain the *net* price $p_{ij}(\varphi) = \tilde{p}_{ij}(\varphi)/(1 + t_{ij})$ earned by the firm, which is used to compute net revenue of the firm. Profits of the the firm are then

$$\pi_{ij}(\varphi) = \max_{p_{ij}(\varphi) \geq 0} \left\{ p_{ij}(\varphi) \, \tilde{q}_{ij}(\varphi) - \frac{x_i}{\varphi} \tau_{ij} \tilde{q}_{ij}(\varphi) - f_{ij} \right\}. \qquad (4)$$

Direct calculation of the integrals below shows that the analogous expression for R2, but now in the presence of revenue tariffs, becomes

$$\underbrace{\int_{\varphi_{ij}^*}^{\infty} \pi_{ij}(\varphi) \, dG(\varphi)}_{\Pi_{ij} \equiv \text{ profits from } j} = \frac{\sigma - 1}{\sigma \theta} \underbrace{\int_{\varphi_{ij}^*}^{\infty} p_{ij}(\varphi) \, \tilde{q}_{ij}(\varphi) \, dG(\varphi)}_{R_{ij} \equiv \text{ revenue earned by firms from } j} . \qquad (5)$$

A clear difference between (2) and (5) is that the former uses revenue $\widetilde{R}_{ij}$ paid by consumers, whereas the latter uses revenue R_{ij} earned by firms, and these differ when *ad valorem* revenue tariffs are used.[8] This difference is immaterial,

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[8]In contrast, with iceberg trade costs then c.i.f. revenue paid by consumers (at c.i.f. prices but with quantity net of iceberg costs) equals the f.o.b. revenue earned by firms (at lower f.o.b. prices but with quantity gross of iceberg costs).

Table 1: Operation of the entry margin under different forms of trade costs

		No rebate		Rebate	
Icebergs	**No:**	$N_i = \frac{\sigma-1}{\sigma\theta}\frac{1}{f_i^E}L_i$		Not applicable	
Cost tariffs	**No:**	$N_i = \frac{\sigma-1}{\sigma\theta}\frac{1}{f_i^E}L_i$	**Yes:**	$N_i = \frac{\sigma-1}{\sigma\theta}\frac{1}{w_i f_i^E}\left(w_i L_i + T_i\right)$	
Revenue tariffs	**Yes:**	$N_i = \frac{\sigma-1}{\sigma\theta}\frac{1}{w_i f_i^E}\left(w_i L_i - T_i\right)$	**No:**	$N_i = \frac{\sigma-1}{\sigma\theta}\frac{1}{f_i^E}L_i$	

Note: The table shows whether the entry margin is operative or not for each combination of trade costs and rebates in a one-sector model with Pareto productivity draws. See text and Appendix A.

however, when the tariff revenue is fully rebated. In that case the labor earnings *paid by the firm* are still L_i, equal to the labor endowment. Then summing over destination markets j, firm revenue net of tariffs is $R_i = L_i$. It follows that entry is determined by $N_i f_i^E = \Pi_i = \frac{\sigma-1}{\sigma\theta}R_i = \left(\frac{\sigma-1}{\sigma\theta}\right)L_i$, which is again fixed as in (3).

Yet, as the reader may anticipate, a careful re-examination of these two cases shows that entry is *not* fixed under alternative assumptions on the tariff rebate. For example, with full rebate of the revenue under cost tariffs, we would obtain $N_i = \frac{\sigma-1}{\sigma\theta}\frac{1}{w_i f_i^E}\tilde{R}_i$. The consumer expenditure $\widetilde{R}_i$ in country i is at tariff-inclusive prices is given by $\widetilde{R}_i = w_i L_i + T_i$, which depends on the collected tariff revenue T_i. Therefore entry depends on the tariff, and is given by

$$N_i = \frac{\sigma-1}{\sigma\theta}\frac{1}{w_i f_i^E}\left(w_i L_i + T_i\right).$$

Alternatively, with no rebate under revenue tariffs, then country i tariff revenue T_i is wasted. It follows that in this case we have that $N_i = \frac{\sigma-1}{\sigma\theta}\frac{1}{w_i f_i^E}R_i$, where $R_i = w_i L_i - T_i$. Therefore entry again depends on the tariff, and is given by

$$N_i = \frac{\sigma-1}{\sigma\theta}\frac{1}{w_i f_i^E}\left(w_i L_i - T_i\right).$$

Table 1 summarizes all of the above results, which apply to the benchmark case of the one-sector model with Pareto productivity draws. It is worth emphasizing an important and novel insight from these results, which is that the existence of a revenue effect coming from a tariff rebate is *neither necessary nor sufficient* to generate changes in entry.

As the table shows, given the variety of possible trade cost formulations any analysis of the impact of tariffs on entry and welfare could in principle consider

all four hypothetical tariff/rebate configurations. But in this paper we focus exclusively on *ad valorem* tariffs applied to the revenue of imports. This choice is made for two reasons. First, we feel that these tariffs are much more realistic, since the alternative cost-based tariffs in CR and FJL (2015) are applied only to the *variable* costs of an import, and not to their fixed operating costs. We do not believe that such a distinction between variable and fixed costs is made when the customs value of an import shipment is claimed at the border.[9] But the second, more important reason, comes from our finding above that entry is fixed in the one-sector model when using revenue tariffs. This is a very convenient, and conservative, starting point for our broader analysis of tariffs, that now builds out from the earlier literature.

To move beyond the one-sector case, suppose now that tariffs are applied to the revenue of imports in a tradable heterogeneous-firm sector, but that there is another, nontaxed sector in the economy (say, nontraded goods). The impact on entry and on welfare will depend on the size of the nontaxed sector and also on the extent of the (traded) intermediate inputs. Indeed, paradoxically, if these are high enough, we will show analytically that, conditional on the level of trade, the *ad valorem* tariffs can result in *lower* welfare than iceberg transport costs, despite the fact that the iceberg costs are thrown into the ocean whereas the tariffs are rebated to consumers! In other words, our analytical results will show quite different—and potentially much greater—effects of revenue tariffs as compared to iceberg trade costs in a two-sector model, depending on the importance of the nontaxed sector and intermediate inputs.

We present our general model next, and then derive analytical results from a symmetric, two-sector, two-country version of the model. Following that, we turn to the major quantitative part of the paper. Like Balistreri et al. (2011) and CR, we calibrate our model to the input-output structure found in actual economies, but we go beyond these authors: we include input-output data for a greater number of developed and developing countries; we also include more low-income countries with large tariff distortions; we use actual multilateral tariff reductions in the 1980s–2010s period (including the Uruguay Round), with highly disaggregate tariffs, to capture the actual changes in trade policy.

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[9]Under the rules of the World Trade Organization, *ad valorem* tariffs are applied to the "customs value" of an import product, which is intended to reflect the price paid between unrelated parties. Such a price should, obviously, not exclude fixed costs or markups/profits. See: http://www.wto.org/english/tratop_e/cusval_e/cusval_info_e. htm.
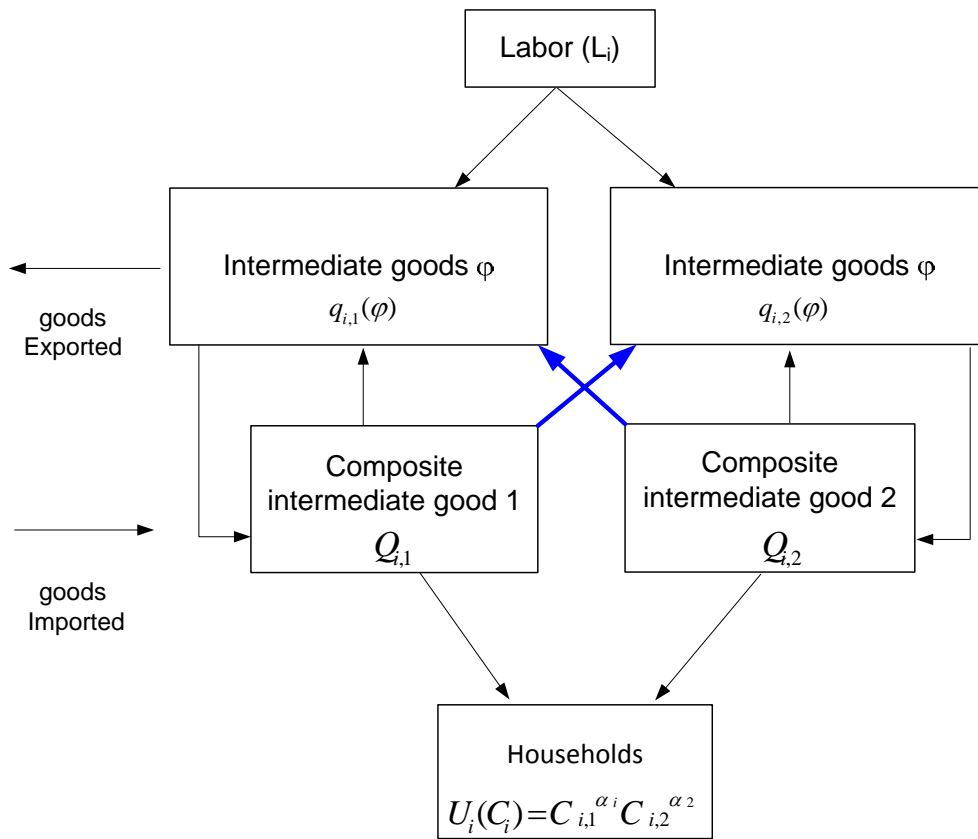
3 Model

The schematic production structure of the model is shown in Figure 1; it follows CP, and was also adopted by CR. We consider a world with M countries, indexed by i and j. There are S sectors, producing final or intermediate goods, indexed by s and s'. There is a mass L_i of identical agents in each economy. Agents consume nontradable final goods from all sectors. The final goods in turn are produced with intermediate goods from different sources, either traded or nontraded. Final goods are also used as materials, i.e., inputs, for the production of intermediate goods, along with raw labor. Intermediate goods producers in each sector s have heterogenous productivities φ. Upon entry, for which it pays a fixed cost, a firm's φ is drawn from the known distribution of productivities $G_s(\varphi)$, where we assume that $G_s(\varphi) = 1 - \varphi^{-\theta_s}$ follows a Pareto distribution with coefficient $\theta_s > 0$. We further impose the standard condition that $\theta_s + 1 > \sigma_s$, where σ_s is the elasticity of substitution of intermediate varieties defined later, so as to ensure that average aggregate productivity under constant elasticity of substitution (CES) aggregation is well defined.

In addition to fixed entry costs, the intermediate goods producers face fixed operating costs, and costs of trading, in all markets. As regards trading costs, traded intermediate goods are subject to two types of bilateral trade frictions: an *ad valorem* tariff $t_{ij,s}$ applied to the *revenue cost* of imports from i to j, and an iceberg trade cost of *ad valorem* form $\tau_{ij,s} - 1 > 0$ of shipping goods from i to j, where we assume $t_{ii,s} = 0$ and $\tau_{ii,s} = 1$ for all i, s. Intermediate goods producers decide how much to supply to the domestic market and how much to supply abroad. Intermediate producers in sector s and country i pay a fixed operating cost $f_{ij,s}$ in order to produce goods for market j, and we make the standard assumption that home operation is less costly than export operation, so that $f_{ii,s} < f_{ij,s}$ for all $j \neq i$. As a result of these fixed costs, less efficient producers of intermediate goods do not find it profitable to supply certain markets, and some do not operate even in the home market. We denote by $\varphi^*_{ij,s}$ the cutoff or threshold productivity level such that all firms in each sector s and country i with $\varphi < \varphi^*_{ij,s}$ are not active in exporting to country j, or not active in the home market, in the case where $\varphi < \varphi^*_{ii,s}$.

Denote by $N_{j,s}$ the mass of entering firms in equilibrium in each sector s and country j. By virtue of the Pareto distribution, the number of firms/products actually sold in sector s, from country j, into market i is the the total number

Figure 1: Schematic production structure of the model

Labor (L_i)

Intermediate goods φ
$q_{i,1}(\varphi)$

Intermediate goods φ
$q_{i,2}(\varphi)$

goods
Exported

Composite
intermediate good 1
$Q_{i,1}$

Composite
intermediate good 2
$Q_{i,2}$

goods
Imported

Households
$U_i(C_i) = C_{i,1}{}^{\alpha_i} C_{i,2}{}^{\alpha_2}$

of entering firms times the mass of firms above the relevant threshold, which is given by $N_{j,s}\left[1 - G_s\left(\varphi^*_{ji,s}\right)\right] = N_{j,s}\varphi^{*}_{ji,s}{}^{-\theta_s}$.

3.1 Households

Assume that agents consume only domestically produced nontraded final goods with preferences given by

$$U_i\left(C_i\right) = \prod_{s=1}^{S}\left(C_{i,s}\right)^{\alpha_{i,s}}, \tag{6}$$

where $C_{i,s}$ is the consumption of a final good type with sector index s and produced in country i, and the $\alpha_{i,s}$ are standard expenditure shares.[10]

Demand is then given by

$$C_{i,s} = \frac{\alpha_{i,s}R_i}{\tilde{P}_{i,s}}, \tag{7}$$

where R_i represents the income of the agents in country i, and $\tilde{P}_{i,s}$ is the price of final good s in country i. Note that we use a tilde to denote *consumer prices*, which are inclusive of tariffs (and iceberg costs). Agents derive income from two sources, labor income and rebated tariff revenue, as explained below; firm profits will be equal to zero by free entry.

3.2 Final goods producers

Assume final goods are assembled from tradable intermediates using no labor. Specifically, final goods are produced with a CES production function with elasticity of substitution equal to $\sigma_s > 1$ using only intermediate varieties as inputs.[11]

The cost minimization problem of the final good producers in each sector s and country i is then

$$\min_{\{\tilde{q}_{ji,s}(\varphi)\}\geq 0} \sum_{j=1}^{M} N_{j,s} \int_{\varphi^*_{ji,s}}^{\infty} \tilde{p}_{ji,s}\left(\varphi\right)\tilde{q}_{ji,s}\left(\varphi\right)g_s\left(\varphi\right)d\varphi,$$

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[10]The final goods are inherently nontraded by assumption, e.g., due to prohibitive iceberg costs.

[11]Intermediate good producers are heterogeneous in their productivity levels and since a particular variety is related to a particular productivity throughout the paper we will abuse notation and denote by φ both the productivity level and variety of the firm.

subject to

$$
\left(\sum_{j=1}^{M} N_{j,s} \int_{\varphi_{ji,s}^{*}}^{\infty} \tilde{q}_{ji,s}\left(\varphi\right)^{\frac{\sigma_s-1}{\sigma_s}} g_s\left(\varphi\right) d\varphi \right)^{\frac{\sigma_s}{\sigma_s-1}} \leq Q_{i,s},
$$

where $\tilde{q}_{ji,s}\left(\varphi\right)$ is the demand by country i and sector s of an intermediate variety φ from country j with the tariff-inclusive price $\tilde{p}_{ji,s}\left(\varphi\right)$, $g_s\left(\varphi\right)$ is the density of $G_s\left(\varphi\right)$, $Q_{i,s}$ is the total quantity of final goods produced, and $N_{j,s}$ is the number of entering firms in country j and sector s. As noted above, the number of firms/products actually sold to market i is $N_{j,s}\left[1 - G_s\left(\varphi_{ji,s}^{*}\right)\right] = N_{j,s}\varphi_{ji,s}^{*}{}^{-\theta_s}$. Note that $\tilde{q}_{ji,s}\left(\varphi\right) > 0$, and the good is produced by j for i, if and only if $\varphi \geq \varphi_{ji,s}^{*}$. Otherwise $\tilde{q}_{ji,s}\left(\varphi\right) = 0$, which accounts for the lower limit of the integral.

From the standard solutions to this CES problem we find that the demand for intermediate goods of variety φ sold in sector s from j to i is given by

$$
\tilde{q}_{ji,s}\left(\varphi\right) = \left(\frac{\tilde{p}_{ji,s}\left(\varphi\right)}{\tilde{P}_{i,s}} \right)^{-\sigma_s} \frac{Y_{i,s}}{\tilde{P}_{i,s}}, \tag{8}
$$

where $Y_{i,s} = \tilde{P}_{i,s}Q_{i,s}$ is the value of output of the final good s in i, and $\tilde{P}_{i,s}$ is the aggregate price index for sector s in i (CES, over all varieties) inclusive of tariffs, which is given by

$$
\tilde{P}_{i,s} = \left(\sum_{j=1}^{M} N_{j,s} \int_{\varphi_{ji,s}^{*}}^{\infty} \tilde{p}_{ji,s}\left(\varphi\right)^{1-\sigma_s} g_s\left(\varphi\right) d\varphi \right)^{\frac{1}{1-\sigma_s}}. \tag{9}
$$

3.3 Intermediate goods producers

Denote the quantity produced by a tradable intermediate goods producer in sector s in country i with variety φ by $\tilde{q}_{i,s}\left(\varphi\right)$. In order to produce, the intermediate goods producer employs labor and uses materials from all sectors and combines them using the following constant returns to scale production function

$$
\tilde{q}_{i,s}\left(\varphi\right) = \varphi l_{i,s}\left(\varphi\right)^{\gamma_{i,s}} \prod_{s'=1}^{S} m_{i,s's}\left(\varphi\right)^{\gamma_{i,s's}}, \tag{10}
$$

where φ is productivity, $l_{i,s}\left(\varphi\right)$ is labor demand, $m_{i,s's}\left(\varphi\right)$ is the quantity of materials used from sector s', $\gamma_{i,s} \geq 0$ is the share in output of value added (here, labor costs), and $\gamma_{i,s's} \geq 0$ is the share in output of the cost of inputs from sector s'

used by sector s (input-output coefficients). We assume that the cost shares sum to unity, $\sum_{s'=1}^{S} \gamma_{i,s's} + \gamma_{i\,s} = 1$.

Cost minimization We solve the problem of the tradable intermediate variety producer in two stages. First, we determine the minimum cost of producing a given quantity. The solution to this problem is the cost function of the firm. Second, we solve for the profit maximization problem of the firm using the cost function derived in the first stage.

The cost minimization problem of the tradable intermediate good of variety φ in country i is given by

$$C\left(\tilde{q}_{i,s}\left(\varphi\right); w_i, \{\tilde{P}_{i,s'}\}_{s'=1}^{S}\right) = \min_{(l_i(\varphi),\{m_{i,s's}(\varphi)\}_{s'=1}^{S})\geq 0} w_i l_{i,s}\left(\varphi\right) + \sum_{s'=1}^{S} \tilde{P}_{i,s'} m_{i,s's}\left(\varphi\right),$$

subject to (10), where w_i denotes the wage in country i.

From the first order conditions of this problem, the demand for labor in the production of variety φ in each sector s is given by

$$l_{i,s}\left(\varphi\right) = \gamma_{i,s} \frac{x_{i,s}}{w_i} \frac{\tilde{q}_{i,s}\left(\varphi\right)}{\varphi},$$

and the demand for intermediate inputs is given by

$$m_{i,s's}\left(\varphi\right) = \gamma_{i,s's} \frac{x_{i,s}}{\tilde{P}_{i,s'}} \frac{\tilde{q}_{i,s}\left(\varphi\right)}{\varphi},$$

where in the last expression we introduce a newly-defined term

$$x_{i,s} \equiv \left(w_i/\gamma_{i,s}\right)^{\gamma_{i,s}} \prod_{s'=1}^{S} \left(\tilde{P}_{i,s'}/\gamma_{i,s's}\right)^{\gamma_{i,s's}}, \tag{11}$$

and we refer to this price index $x_{i,s}$ as the cost of the input bundle or more simply as the *input cost* index. The input cost index contains information on prices from all sectors in the economy and, clearly, the input cost directly affects production decisions in all sectors. This is one key distinction of our model as compared to a one-sector model or a multi-sector model without input-output linkages.

The solution to the cost minimization problem yields the following (variable)

cost function for each producer of variety φ in country i and sector s:

$$C\left(\tilde{q}_{i,s}\left(\varphi\right);x_{i,s}\right)=\frac{x_{i,s}}{\varphi}\tilde{q}_{i,s}\left(\varphi\right). \tag{12}$$

The marginal cost of each producer is then given by

$$MC_{i,s}\left(\tilde{q}_{i,s}\left(\varphi\right);x_{i,s}\right)=\frac{x_{i,s}}{\varphi}. \tag{13}$$

Profit maximization We now solve for the profit maximizing quantity of the intermediate variety producer assuming monopolistic competition. Producers in country i pay a sector-specific fixed operating cost to sell into each market j, denoted by $f_{ij,s}$. For simplicity we suppose that this cost is paid in units of labor.

Note that since the production technology is linear we can solve the profit maximization problem for each individual market separately. Consider the profit maximization problem of supplying goods to market j. Profits are given by

$$\pi_{ij,s}\left(\varphi\right)=\max_{p_{ij,s}(\varphi)\geq 0}\left\{p_{ij,s}\left(\varphi\right)\tilde{q}_{ij,s}\left(\varphi\right)-\frac{x_{i,s}}{\varphi}q_{ij,s}\left(\varphi\right)-w_{i}f_{ij,s}\right\}, \tag{14}$$

subject to (8). The control variable in this problem is $p_{ij,s}\left(\varphi\right)=\frac{\tilde{p}_{ij,s}(\varphi)}{1+t_{ij,s}}$, the net-of-tariff price received by the exporting firm.

As we can see, this price differs from the tariff-inclusive price $\tilde{p}_{ij,s}\left(\varphi\right)$ paid by the importer, and means that the sales revenue $\tilde{p}_{ij,s}\tilde{q}_{ij,s}$ is *divided by* the tariff factor $1+t_{ij,s}$ in order to obtain producer revenue in (14). Note that the quantity sold by the firm is $q_{ij,s}\left(\varphi\right)=\tau_{ij,s}\tilde{q}_{ij,s}\left(\varphi\right)$ because of the iceberg trade costs. So the costs of production $(x_{i,s}/\varphi)\tilde{q}_{ij,s}$ are *multiplied by* the iceberg trade costs $\tau_{ij,s}$ to obtain the costs in (14).

These are subtle but very important details. This discussion shows how the tariffs and iceberg trade costs enter the profit equation in slightly different ways, and follows from our reality-based assumption that the *ad valorem* tariff is applied to the sales revenue. In contrast, if the tariff was applied to only the costs of the imported product then the costs $(x_{i,s}/\varphi)\tilde{q}_{ij,s}$ would be multiplied by the product of the iceberg trade costs and the tariff factor, $\tau_{ij,s}(1+t_{ij,s})$ in (14), so that the tariffs and iceberg costs would enter the firm's problem symmetrically.[12]

We will see that this distinction between how tariffs and iceberg costs are

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[12]For clarity, the profit maximization equation in the case where the tariff was applied to firm *revenue* for the imported product (i.e., the net-of-tariff, post-markup) price would be as in (14), and

modeled makes an important difference to the zero-profit-cutoff productivity that we solve for below.

The first order conditions of this CES producer problem can be solved for the quantity sold and price charged, as follows, making use of the CES demand function at (8). As in the standard solution, price charged is the usual markup over unit cost pre-tariff (input cost index, adjusted for productivity, and also scaled by the iceberg factor since it is a destination pre-tariff price). The quantity demanded is then a function of this price plus the tariff, relative to the price index of all intermediates in sector s in destination market i.

$$
\tilde{q}_{ij,s}(\varphi) = \left(\frac{\sigma_s}{\sigma_s - 1} \frac{\tau_{ij,s} x_{i,s}}{\varphi} \right)^{-\sigma_s} \frac{\tilde{P}_{j,s}^{\sigma_s - 1} Y_{j,s}}{\left(1 + t_{ij,s}\right)^{\sigma_s}}, \tag{15}
$$

$$
p_{ij,s}(\varphi) = \frac{\sigma_s}{\sigma_s - 1} \frac{x_{i,s} \tau_{ij,s}}{\varphi}. \tag{16}
$$

Using these two expressions, we can then multiply to get the revenues for sector s in country i from selling to market j as given by

$$
r_{ij,s}(\varphi) = p_{ij,s}(\varphi) \tilde{q}_{ij,s}(\varphi) = \left(\frac{\sigma_s}{\sigma_s - 1} \frac{x_{i,s} \tau_{ij,s}}{\varphi} \right)^{1 - \sigma_s} \frac{\tilde{P}_{j,s}^{\sigma_s - 1} Y_{j,s}}{\left(1 + t_{ij,s}\right)^{\sigma_s}}.
$$

The profits for sector s in country i from selling to market j are given by the markup minus one, times unit cost pre-tariff, times output, less fixed costs:

$$
\pi_{ij,s}(\varphi) = \frac{1}{\sigma_s - 1} \left(\frac{x_{i,s} \tau_{ij,s} \tilde{q}_{ij,s}(\varphi)}{\varphi} - (\sigma_s - 1) w_i f_{ij,s} \right). \tag{17}
$$

we can scale that up by a factor $(1 + t_{ij,s})$ to get

$$
(1 + t_{ij,s}) \pi_{ij,s}(\varphi) = \max_{p_{ij,s}(\varphi) \geq 0} \left\{ \tilde{p}_{ij,s}(\varphi) \tilde{q}_{ij,s}(\varphi) - \frac{x_{i,s}}{\varphi} \tau_{ij,s}(1 + t_{ij,s}) \tilde{q}_{ij,s}(\varphi) - w_i f_{ij,s}(1 + t_{ij,s}) \right\},
$$

and where the tariff was applied to only the firm *cost* for the imported product would be

$$
\pi_{ij,s}(\varphi) = \max_{p_{ij,s}(\varphi) \geq 0} \left\{ \tilde{p}_{ij,s}(\varphi) \tilde{q}_{ij,s}(\varphi) - \frac{x_{i,s}}{\varphi} \tau_{ij,s}(1 + t_{ij,s}) \tilde{q}_{ij,s}(\varphi) - w_i f_{ij,s} \right\},
$$

where in both expressions we use the firm's destination price $\tilde{p}_{ij,s}$ and quantity sold $\tilde{q}_{ij,s}$, to make for comparability. From these two equations, viewed side-by-side, it is obvious that in the latter case the effect of cost tariffs and icebergs are totally symmetric, entering as $\tau_{ij,s}(1 + t_{ij,s})$, and setting aside the income effects arising for the cost tariff rebate which are absent in the case of icebergs. It is this feature that has been exploited to simplify matters in the previous literature, but it is a path not taken in this paper.

3.4 Selection and Entry

Zero cutoff profit condition   As usual, following Melitz (2003), the first-stage fixed costs of entry $f_{i,s}^E$ in each sector s and country i are assumed to be covered by a lump-sum mutual-fund arrangement which pays out to all firms that enter, whether they are non-operators, domestic operators, or export operators. This scheme operates in the background, and ensures ex ante expected profits are zero at the first-stage decision, which governs the *entry* of firms. This leaves only the second-stage fixed costs of operation $f_{ij,s}$ for each sector s and exporter-importer pair ij to be considered, which govern the the *selection* of firms into non-operators, domestic operators, or export operators according to another set of zero expected profit conditions.

Given the presence of fixed operating costs, there exits a threshold level of productivity such that a firm in a given sector makes zero profit. We can characterize the threshold or cut-off level of productivity of operating firms by looking at the profits of the marginal firm producer. In particular, the zero cutoff profit (ZCP) level of productivity is determined by

$$\pi_{ij,s}\left(\varphi_{ij,s}^*\right) = 0.$$

Using the equilibrium conditions for prices and quantities derived before, the ZCP level of productivity in sector s is given by

$$\varphi_{ij,s}^* = \left(\frac{\sigma_s}{\sigma_s - 1}\right)\left(\frac{\sigma_s w_i f_{ij,s}}{Y_{j,s}}\right)^{\frac{1}{\sigma_s - 1}} \frac{x_{i,s}\tau_{ij,s}\left(1 + t_{ij,s}\right)^{\frac{\sigma_s}{\sigma_s - 1}}}{\tilde{P}_{j,s}}. \tag{18}$$

The threshold level of productivity is a function of the elasticity of demand, fixed operating costs, the cost of the input bundle, the price index, total expenditure and trade costs. The larger are the fixed or variable costs of exporting and the cost of the input bundle, the larger is the ZCP level of productivity to enter into the export market. Expansions in market j, captured by a larger $Y_{j,s}$, or increases in the price index, $\tilde{P}_{j,s}$ lower the threshold level of productivity. Note that there is a ZCP condition for each sector in the economy and that they are all related by the input-output linkages presented on the cost of the input bundle. Changes in trade cost of one good will affect the input bundle and in turn change the ZCP level of productivity on another sector. The extent to which sectors are related, namely the interconnections presented in the input-output table will determine the extent to which changes in trade costs in one sector will impact other sectors.

Note that a reduction in the tariff level affects the ZCP condition in a way that is different from a reduction in iceberg trade costs. This follows from our assumption that tariffs are applied to the sales value of the import, as discussed above. In practice, this means that a reduction in actual tariffs acts in the ZCP condition very similarly to a *joint reduction* in iceberg trade costs an in fixed costs. To see this, we can rearrange (18) in the following way

$$\varphi_{ij,s}^{*} = \left(\frac{\sigma_s}{\sigma_s - 1} \right) \left(\frac{\sigma_s w_i f_{ij,s} \left(1 + t_{ij,s} \right)}{Y_{j,s}} \right)^{\frac{1}{\sigma_s - 1}} \frac{x_{i,s} \tau_{ij,s} \left(1 + t_{ij,s} \right)}{\tilde{P}_{j,s}}. \tag{19}$$

This equation makes clear that changes in the *ad valorem* tariff $t_{ij,s}$ act in the same manner as a *joint* change in $f_{ij,s}$ and $\tau_{ij,s}$.

We remark that, in contrast, if tariffs are applied only to the costs of imported products, then they would have exactly the same effect on the zero-cutoff-profit condition as do iceberg trade costs $\tau_{ij,s}$, and would appear only as multiplying those trade costs above (i.e., as in the final term). Still, as we argue in Appendix A, *ad valorem* tariffs applied to the costs of imports will have an impact on the entry of firms, in contrast to iceberg transport costs. Under our maintained assumption that tariffs are applied to the sales revenue, they have the "extra" impact of effectively reduced fixed costs, too. The gains from tariff reduction will take into account this implicit reduction in fixed costs, which will act so as to encourage the entry of exporters and increase export variety, as we show below.

Free entry Firms pay a fixed cost of entry $f_{i,s}^{E}$ in each sector, in units of labor, in order to allow them to take a draw from the known distribution of productivities $G_s (\varphi)$. Free entry implies that expected profits of firms have to be equal to entry costs at each market s,

$$\sum_{j=1}^{M} \int_{\varphi_{ij,s}^{*}}^{\infty} \pi_{ij,s} (\varphi) \, g_s (\varphi) \, d\varphi = w_i f_{i,s}^{E}.$$

Using the equilibrium conditions (17) and (18) and given the assumption of Pareto distribution of productivities we end up with the following equilibrium condition

$$\sum_{j=1}^{M} f_{ij,s} \varphi_{ij,s}^{* -\theta_s} = \frac{\theta_s - \sigma_s + 1}{\sigma_s - 1} f_{i,s}^{E}, \tag{20}$$

that relates the ZCP levels of productivities to the fixed operating and entry costs.

3.5 Price index

We define the average productivity in sector s of intermediate goods in market i sourced from market j as

$$\tilde{\varphi}_{ji,s} = \left(\int_{\varphi^*_{ji,s}}^{\infty} \varphi^{\sigma_s - 1} \mu_{ji,s}(\varphi) \, d\varphi \right)^{\frac{1}{\sigma_s - 1}}, \tag{21}$$

where $\mu_{ji,s}(\varphi) = g_s(\varphi) / \left[1 - G_s \left(\varphi^*_{ji,s} \right) \right]$ is the conditional distribution of productivities (conditional on the variety φ being actively produced for this $\{i, j, s\}$ combination). Then using the equilibrium conditions (9), and (16), we obtain

$$\tilde{P}_{i,s} = \left(\sum_{j=1}^{M} \varphi^*_{ji,s}{}^{-\theta_s} N_{j,s} \left(\frac{\sigma_s}{\sigma_s - 1} \frac{x_{j,s} \tau_{ji,s}(1 + t_{ji,s})}{\tilde{\varphi}_{ji,s}} \right)^{1 - \sigma_s} \right)^{\frac{1}{1 - \sigma_s}}, \tag{22}$$

where $\varphi^*_{ji,s}{}^{-\theta_s} = \left[1 - G_s \left(\varphi^*_{ji,s} \right) \right]$ is the probability that an entering firm in country j is actually selling to market i, so that the number of products actually sold are $N_{ji,s} \equiv \varphi^*_{ji,s}{}^{-\theta_s} N_{j,s}$.

3.6 Trade balance and market clearing

Two steps remain to close the model, the first being to ensure that all entities obey their budget constraints, markets clear, and trade is balanced.

Expenditure shares   Recall that $Y_{i,s} = \tilde{P}_{i,s} Q_{i,s}$ is the value of the output of the final good s in country i, which is produced entirely from intermediate goods, these being either imported or produced domestically. Hence, this value of output equals the total expenditure on those intermediate goods.

Let $\lambda_{ji,s}$ denote the share of country's i total expenditure in sector s on intermediate goods from market j. In this share, integrating over sales of all varieties of s from j to i yields the numerator, and summing over all markets j gives the denominator:

$$\lambda_{ji,s} = \frac{N_{j,s} \int_{\varphi^*_{ji,s}}^{\infty} \tilde{p}_{ji,s}(\varphi) \tilde{q}_{ji,s}(\varphi) g_s(\varphi) \, d\varphi}{\sum_{n=1}^{I} N_{n,s} \int_{\varphi^*_{ni,s}}^{\infty} \tilde{p}_{ni,s}(\varphi) \tilde{q}_{ni,s}(\varphi) g_s(\varphi) \, d\varphi}. \tag{23}$$

Using the equilibrium conditions (16) and (22) we can obtain the following ex-

pression for the expenditure share

$$\lambda_{ji,s} = \varphi_{ji,s}^{*}{}^{-\theta_s} N_{j,s} \left(\frac{\sigma_s}{\sigma_s - 1} \frac{\tau_{ji,s} x_{j,s} \left(1 + t_{ji,s}\right)}{\tilde{\varphi}_{ji,s}} \frac{1}{\tilde{P}_{i,s}} \right)^{1-\sigma_s}. \tag{24}$$

Sectoral trade flows We now solve for sectoral exports and imports and impose balanced trade.

Consider sector s imports first. The total expenditure by country i on country j intermediate goods is given by $\lambda_{ji,s} Y_{i,s}$. Due to the presence of tariffs not all of this expenditure reaches producers in country j. The tariff-adjusted expenditure in country j on goods produced in country i, or exports from i to j, is $E_{ij,s} \equiv \frac{\lambda_{ij,s}}{1+t_{ij,s}} Y_{j,s}$.

Of course, that term is identical to imports arriving in j from i. Therefore, total **exports** from country i, *not* including goods that are sold domestically, are given by

$$E_{i,s} \equiv \sum_{j \neq i} E_{ij,s} = \sum_{j \neq i} \frac{\lambda_{ij,s}}{1 + t_{ij,s}} Y_{j,s}, \tag{25}$$

and total **imports** are given by

$$\sum_{j \neq i} E_{ji,s} = \sum_{j \neq i} \frac{\lambda_{ji,s}}{1 + t_{ji,s}} Y_{i,s}. \tag{26}$$

After defining sectoral trade flows we now define the **trade balance** condition

$$\sum_{s=1}^{S} \sum_{j \neq i} \frac{\lambda_{ji,s}}{1 + t_{ji,s}} Y_{i,s} = \sum_{s=1}^{S} \sum_{j \neq i} \frac{\lambda_{ij,s}}{1 + t_{ij,s}} Y_{j,s}. \tag{27}$$

Goods Market Equilibrium We can also define sectoral, $T_{i,s}$, and total, T_i, tariff revenue as

$$T_i = \sum_{s=1}^{S} T_{is} = \sum_{s=1}^{S} \sum_{j \neq i} t_{ji,s} E_{ji,s}. \tag{28}$$

With that, the expenditure on final goods from sector s by households in country i is given by $\alpha_{i,s} I_i$, where I_i is total expenditure consisting of labor income plus this redistributed tariff revenue, $I_i = w_i L_i + T_i$.

The total value of gross production of all intermediate goods in sector s in country i is given by $\frac{\sigma_s - 1}{\sigma_s} \sum_{j=1}^{M} \frac{\lambda_{ij,s}}{1+t_{ij,s}} Y_{j,s}$; namely, the net-of-tariff value of sector s goods that are sold locally and abroad adjusted by markups. Given the input-output coefficients, a share $\gamma_{i,s's}$ of this gross production is then spent on

intermediate inputs from sector s'. Therefore, the materials from sector s' demanded in sector s for the production of intermediate goods is then given by $\gamma_{i,s's}\frac{\sigma_s-1}{\sigma_s}\sum_{j=1}^{M}\frac{\lambda_{ij,s}}{1+t_{ij,s}}Y_{j,s}$.

We can then obtain the total demand for the final good in sector s of country i, which must equal total supply where we sum the demand from consumers for final goods and demand for intermediate use (the term here in braces):

$$Y_{i,s} = \alpha_{i,s}\left(w_i L_i + T_i\right) + \left\{ \sum_{s'=1}^{S} \gamma_{i,ss'}\frac{\sigma_{s'}-1}{\sigma_{s'}} \sum_{j=1}^{M}\frac{\lambda_{ij,s'}}{1+t_{ij,s'}}Y_{j,s'} \right\}, \tag{29}$$

We refer to this condition as the goods market equilibrium.

3.7 Firm Entry and Product Variety

The final step to close the model tackles selection and entry, solving for the mass of firms $N_{i,s}$ entering and the productivity cutoffs $\varphi^*_{ij,s}$ for the varieties produced.

To solve for product variety, we first rewrite (18) as

$$\left(\frac{\sigma_s}{\sigma_s-1}\frac{x_{i,s}\tau_{ij,s}\left(1+t_{ij,s}\right)}{\tilde{P}_{j,s}\varphi^*_{ij,s}} \right)^{1-\sigma_s} = \left(\frac{\sigma_s w_i f_{ij,s}\left(1+t_{ij,s}\right)}{Y_{j,s}} \right). \tag{30}$$

We note that the average value $\tilde{\varphi}_{ij,s}$ is related to the cutoff $\varphi^*_{ij,s}$ by

$$\tilde{\varphi}_{ij,s} = \left(\int_{\varphi^*_{ij,s}}^{\infty} \varphi^{\sigma_s-1}\mu_{ij,s}\left(\varphi\right)d\varphi \right)^{\frac{1}{\sigma_s-1}} = \varphi^*_{ij,s}\left(\frac{1}{\theta_s+1-\sigma_s} \right)^{\frac{1}{\sigma_s-1}}, \tag{31}$$

by the properties of the Pareto distribution. Substituting these last two equations into (24) we can obtain an equation governing the cutoffs $\varphi^*_{ij,s}$

$$\lambda_{ij,s} = \varphi^{*-\theta_s}_{ij,s}N_{i,s}\left(\frac{\sigma_s w_i f_{ij,s}\left(1+t_{ij,s}\right)}{Y_{j,s}} \right)\left(\frac{1}{\theta_s+1-\sigma_s} \right). \tag{32}$$

Next, multiplying by $Y_{j,s}/\left(1+t_{ij,s}\right)$, summing over j and making use of (25) and (20), we obtain

$$E_{ii,s} + E_{i,s} = \sum_{j=1}^{M}\varphi^{*-\theta_s}_{ij,s}N_{i,s}\left(\frac{\sigma_s w_i f_{ij,s}}{\theta_s+1-\sigma_s} \right) = N_{i,s}w_i f^E_{i,s}\left(\frac{\sigma_s}{\sigma_s-1} \right), \tag{33}$$

from which we obtain an equation governing the mass of entrants $N_{i,s}$

$$N_{i,s} = (E_{ii,s} + E_{i,s}) \left/ \left[w_i f_{i,s}^E \left(\frac{\sigma_s}{\sigma_s - 1} \right) \right] \right. .\tag{34}$$

It may appear surprising that total domestic plus international sales of intermediate inputs $(E_{ii,s} + E_{i,s})$ is so tightly linked to the mass of entrants $N_{i,s}$. But recall the condition from ACR that aggregate profits in an economy, which equal entry times the fixed costs of entry, are proportional to the labor force: therefore, entry is fully determined by the labor force in each country. Equation (33) is the analogous result here: entry times fixed costs of entry is proportional to domestic sales plus exports in each sector. But exports depend on *ad valorem* tariffs, as is clear from (25) and the share equations in (24).

4 Illustrative Two-Sector Symmetric Equilibrium

To illustrate some properties of the model by means of a simple example, and to obtain a closed-form solution for comparative statics, we study the special case where countries are all identical and there are two sectors. This analysis is explored in more detail in Appendix B.

Having just two sectors will allow us to enrich the input-output structure. The first sector will be just as we have assumed above, with traded intermediate inputs and a nontraded output good that is consumed and is also used as an intermediate input domestically. So this sector has both backward or forward linkages. The second sector is much simpler and consists of purely nontraded consumer services (e.g., haircuts), which are produced with labor and which neither use nor are used as intermediate inputs. In other words, this residual sector has no backward or forward linkages. This second sector plays a role mainly on the demand side where it has a taste share of $1 - \alpha$, while the first sector has a taste share of α.

The condition (29) applies to the first sector only, and for clarity we drop the summation over sectors s in (29); in fact, furthermore, we can drop the sector subscript altogether. We let $\gamma \equiv \gamma_{i,ss}$ denote the single nonzero term in the input-output matrix for the first sector in each country, with $0 < \gamma < 1$. We assume that the *ad valorem* tariffs are equal across countries, $t_{ij,s} = t$ for $i \neq j$, while $t_{ii,s} = 0$.

Output in the Two-Sector, Symmetric Equilibrium   Rewriting (29), we know that in a symmetric equilibrium $Y_i = Y_j$, so that $\lambda_{ij} = \lambda_{ji}$ and therefore $\sum_{j=1}^{M} \lambda_{ij} =$

$\sum_{j=1}^{M} \lambda_{ji} = 1$. Notice that tariff revenue becomes $T_i = tE_{ji} = t\frac{\lambda_{ji}}{1+t}Y_i = t\frac{(1-\lambda_{ii})}{1+t}Y_i$. Now, without loss of generality, we set wages as the numeraire, and with symmetry $w_i = w_j = 1$, so that (29) becomes

$$Y_i \left[1 - \tilde{\gamma}\left(\frac{1 + \lambda_{ii}t}{1+t} \right) - \alpha t \frac{(1 - \lambda_{ii})}{1+t} \right] = \alpha L_i. \tag{35}$$

where $\tilde{\gamma}$ is given by $0 < \tilde{\gamma} \equiv \gamma\frac{\sigma-1}{\sigma} < 1$.

Totally differentiating this expression and simplifying, we can obtain

$$\frac{dY_i}{Y_i} = \Delta\left[\left(\frac{1 - \lambda_{ii}}{1 + \lambda_{ii}t} \right) \frac{dt}{1+t} - \left(\frac{t}{1 + \lambda_{ii}t} \right) d\lambda_{ii} \right], \tag{36}$$

$$\text{where } \Delta \equiv \left[\frac{\alpha - \tilde{\gamma}}{1 + \frac{t(1-\lambda_{ii})(1-\alpha)}{1+\lambda_{ii}t} - \tilde{\gamma}} \right] < 1. \tag{37}$$

To interpret this result, notice that when evaluated at the neighborhood of the free trade equilibrium ($t \simeq 0$) then a reduction in tariffs will lead to a fall in the value of gross shipments unless $\Delta < 0$. For $\alpha < 1$ we see that $\Delta < 1$ in general, while for $\alpha < \tilde{\gamma}$ then $\Delta < 0$. Thus, it is possible that the reduction in tariffs *raises* gross shipments of the first good, which after all makes use of the cheaper imported inputs. That outcome occurs in particular when the share parameter on the first (differentiated) sector α is sufficiently small, in which case the fall in tariff revenue and hence demand falls mainly on the second sector.

Entry in the Two-Sector, Symmetric Equilibrium   We will now explore how these changes affect firm entry and product variety. To solve for entry, note that domestic sales plus exports are $E_{ii} + E_i = \sum_{j=1}^{M} \frac{\lambda_{ij}}{1+t_{ij}}Y_j = Y_i\left(\lambda_{ii} + \frac{1-\lambda_{ii}}{1+t} \right)$, which follows from symmetry across countries. The final expression is further simplified as $Y_i\left(\frac{1+t\lambda_{ii}}{1+t} \right)$, and so from (34) we obtain

$$N_i = \frac{\lambda_{ii}Y_i + \sum_{j\neq i} \frac{\lambda_{ij}}{1+t}Y_j}{f_i^E\left(\frac{\sigma}{\sigma-1} \right)} = \frac{\sigma - 1}{\sigma f_i^E}\left(\frac{1 + \lambda_{ii}t}{1+t} \right)Y_i, \tag{38}$$

where we continue to normalize the wage at unity and suppress sector subscripts. Then totally differentiating this expression and substituting the change in gross

shipments from (37) and cancelling common terms, we arrive at

$$\frac{dN_i}{N_i} = (\Delta - 1) \left[\left(\frac{1 - \lambda_{ii}}{1 + t\lambda_{ii}} \right) \frac{dt}{1 + t} - \left(\frac{t}{1 + t\lambda_{ii}} \right) d\lambda_{ii} \right]. \tag{39}$$

Two contrasting local properties about tariffs and entry now follow. First, consider a reduction in tariffs around the free trade equilibrium. Here, with $t \simeq 0$ and $dt < 0$, then it is ready seen that $\hat{N}_i > 0$ because $\Delta < 1$. So a small *decrease* in the tariff leads to greater firm entry. But away from the free trade equilibrium then it is quite possible that tariff reductions will inhibit entry. With a tariff reduction we expect that the share of expenditure on home products falls, $d\lambda_{ii} < 0$, which will *offset* the induced entry. But because $d\lambda_{ii}$ is multiplied by t, then this term is second order for small t, whereas the direct effect of the tariff reduction in encouraging entry is of the first order. Therefore: *for positive but small tariffs, decreasing the tariff in the symmetric equilibrium will induce entry.*

Second, consider starting from a situation with prohibitive tariffs. Here we get the opposite result. Under autarky with $\lambda_{ii} = 1$ the first term in brackets on the right of (39) clearly vanishes as tariff revenue disappears. Now suppose we make a small increase in the tariff to just reach $\lambda_{ii} = 1$; this means that $d\lambda_{ii} > 0$, so the second term in brackets on the right is negative, and with $\Delta < 1$, we see now that: *Near autarky, increasing the tariff in the symmetric equilibrium will induce entry.*

Furthermore, we claim a global result: that the level of entry N_i will be the same in the free trade equilibrium (with zero tariffs) and in the autarky equilibrium (with prohibitive tariffs). A bit of intuition for this result is that the autarky equilibrium with prohibitive tariffs is isomorphic to an equilibrium with prohibitive iceberg transport costs, and because entry N_i is independent of iceberg costs, it will therefore be the same as under free trade.

To see the result formally, equation (35) shows that Y_i is the same whether $t = 0$ or $\lambda_{ii} = 1$, and then from (38), we quickly conclude that N_i is the same whether $t = 0$ or $\lambda_{ii} = 1$. Indeed, at both extremes, $Y_i = \alpha L_i / (1 - \tilde{\gamma})$.

We can summarize and sharpen these results for the two-sector symmetric equilibrium as follows:

Theorem 1 *The mass of entering firms N_i is the same under free trade and prohibitive tariffs. If and only if $\alpha < 1$, then: a) near the free trade equilibrium reducing the tariff will increase entry; b) near the prohibitive tariff, reducing the tariff will decrease entry; c) entry is lower at all intermediate tariff levels than under free trade or prohibitive tariffs.*

Proof. Part a) and b) have been shown already, except for the final claim part c). The latter can be seen to follow from (35) and (38), as follows. Normalizing wages at unity, from (35) we see that $Y_i = \alpha L_i / (1 - \tilde{\gamma})$ when $t = 0$ or $\lambda_{ii} = 1$. It follows from (38) that $N_i = (\sigma - 1)\alpha L_i / [(1 - \tilde{\gamma})\sigma f_i^E]$ when $t = 0$ or $\lambda_{ii} = 1$. Then $N_i \leq (\sigma - 1)\alpha L_i / [(1 - \tilde{\gamma})\sigma f_i^E]$ at all other tariff equilibria provided that for $t > 0$ and $\lambda_{ii} < 1$,

$$\left(\frac{1 + t\lambda_{ii}}{1 + t} \right) \Big/ \left[1 - \tilde{\gamma}\left(\frac{1 + \lambda_{ii}t}{1 + t} \right) - \alpha t \frac{(1 - \lambda_{ii})}{1 + t} \right] < \frac{1}{(1 - \tilde{\gamma})}.$$

Straightforward but tedious algebra shows this condition is satisfied for $\alpha < 1$. ∎

We think it is important to step back and understand what this result implies. It says that, for this class of models: *there must be a nontraded sector present in order for import tariffs to influence entry*. Notice that without such a nontraded sector we have $\alpha = 1$ and hence $\Delta = 1$ in (37), and then we would necessarily have fixed entry with $dN_i = 0$ in (39).

To go a little further, we can turn to numerical simulations of the two-sector symmetric model to see more clearly how entry is affected by tariffs in different configurations of the model. Figure 2 shows how the level of firm entry N_i and the domestic share λ_{ii} varies as the tariff level t changes over the range from free trade to autarky, for different values of the traded sector share α.

Entry is the same under free trade and autarky. Entry is also constant when the nontraded sector is absent and $\alpha = 1$. Otherwise, starting close to free trade entry falls as tariffs increase from zero, before then rising again in a ∪-shape after some point as tariffs approach prohibitive levels. The ∪-shape is more pronounced as the nontraded sector grows in size (i.e., as α falls further below 1).

Welfare in the Two-Sector, Symmetric Equilibrium   We next obtain a closed-form expression for the change in welfare in the simple model in the presence of tariffs and input-output linkages.

So far, we have not had to be explicit about the structure of the second sector, which provides consumer services produced with labor alone. For simplicity, let us now suppose that the second sector is competitive and that, without loss of generality, productivity is unity so that the price of a unit of service equals the wage. Already the wages in each country are normalized at unity, so that the service price is also constant and equal to one in both countries.

Figure 2: Entry effects of tariffs changes in the two-sector symmetric model
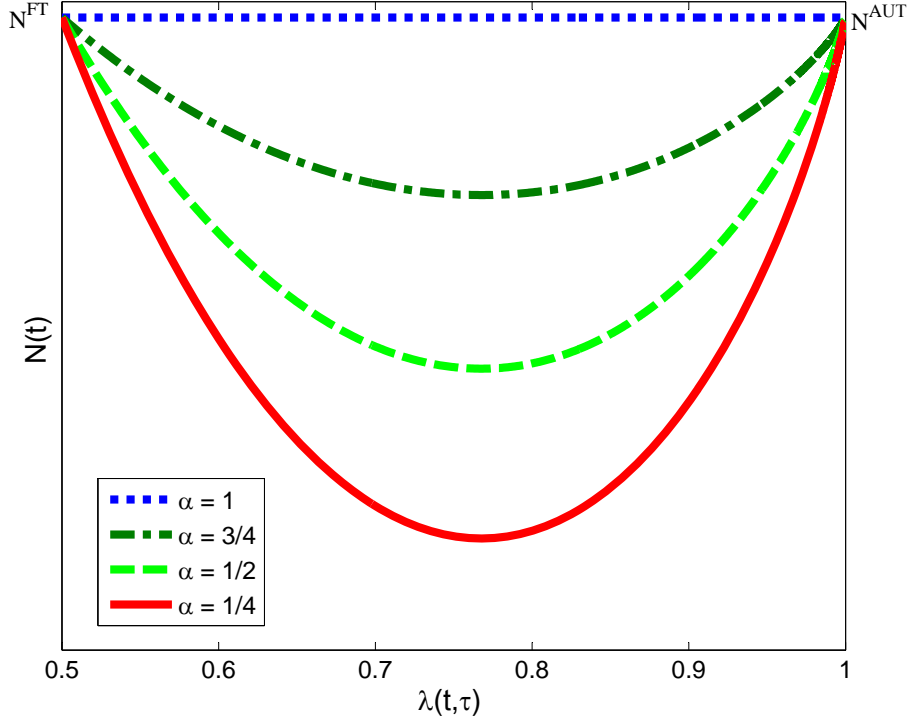
Note: This figure shows how the level of firm entry N_i and the domestic share $\lambda = \lambda_{ii}$ vary as the tariff $t = t_{ij}$ changes, for different values of the traded sector share $\alpha \in \{1, 0.75, 0.5, 0.25\}$, with $t \in (0, \infty)$ and no iceberg costs, $\tau = 1$. The other model parameters are $\sigma = 2, \theta = 4, f_D = f_{ii} = 1, f_X = f_{ij} = 1,$ and $f_i^E = 1$.

It then follows that the change in welfare from (6) and (7) is given by

$$\frac{dU_i}{U_i} = -\alpha \frac{d\tilde{P}_i}{\tilde{P}_i} + \frac{dT_i}{w_i L_i + T_i}, \tag{40}$$

where $\tilde{P}_i$ is the price index for the differentiated good that used traded inputs, and $R_i = w_i L_i + T_i$ is consumer's income inclusive of tariff revenue.

The first term on the right of (40) is the change in the price index, which can be computed from (22) as

$$\frac{d\tilde{P}_i}{\tilde{P}_i} = \frac{1}{1-\gamma} \frac{d\lambda_{ii}}{\theta \lambda_{ii}} - \frac{1}{1-\gamma} \left[\frac{1}{\theta} + \left(\frac{1}{\sigma - 1} - \frac{1}{\theta} \right) \frac{\Delta}{\Delta - 1} \right] \frac{dN_i}{N_i}. \tag{41}$$

The first term on the right looks familiar: it is just how the price index changes based on the implied change in the domestic share $d\lambda_{ii}$. The second term is new:

it reflects the entry margin we have introduced. This term, which depends on the changing entry of firms in the differentiated sector, does not arise when evaluating the welfare gains from reducing icebergs because entry does not change.

Combining these last two expression, the change in welfare is given by

$$\frac{dU_i}{U_i} = \underbrace{-\frac{\alpha}{1-\gamma}\frac{d\lambda_{ii}}{\theta\lambda_{ii}}}_{\text{trade volume}} + \underbrace{\xi\frac{dN_i}{N_i}}_{\text{entry}} + \underbrace{\frac{dT_i}{w_iL_i + T_i}}_{\text{tariff rebate}}. \tag{42}$$

where $\xi = \frac{\alpha}{1-\gamma}\left[\frac{1}{\theta} + \left(\frac{1}{\sigma-1} - \frac{1}{\theta}\right)\frac{\Delta}{\Delta-1}\right]$. Now, as the reader may have grasped from our earlier discussion of icebergs, cost tariffs, and revenue tariffs, this general expression for welfare gains would inevitably vary if model assumptions were changed. Most clearly, we know that in the simplest model of pure icebergs with no tariffs, there will be no change in entry, as we noted before, and there is no tariff rebate, by construction; thus, the second and third terms disappear, and we would be left with the first term on the right of (42), and this formula echoes the result in ACR. In a different model framework, if non-Pareto productivity draws were introduced, we know it is possible for the entry margin to become active in the second term under icebergs, but still with the third term at zero with no tariff rebate; here this formula echoes the result in Melitz and Redding (2015).[13] However, in the setting we study in this paper—with iceberg costs *and* revenue tariffs present, and even with Pareto draws—all three terms in this expression become nonzero, leading us naturally into a discussion of the signs and relative magnitudes of these three different components of welfare change.[14]

A natural place to start the discussion of these subtleties is in the neighborhood of what we call a free trade equilibrium (FT), which is to say where tariffs are zero ($t = 0$), but icebergs may be set at any arbitrary level ($\tau \geq 1$). In many simple old and new trade models, a very standard result is that for a small, first-order change in (rebated) tariffs near free trade, welfare losses will be *second-order* small, whilst for a small, first-order change in iceberg costs (or, say, nonrebated tariffs), welfare losses will be *first-order* small. This often amounts to the difference between the area of a Harberger triangle versus size of the tax revenue rectangle.

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[13]Of course, the elasticity of welfare with respect to entry is not constant, in general, in the Melitz and Redding (2015) framework.

[14]FJL (2015, Proposition 1) include a tariff revenue term in their expression for welfare, but not an entry term, which they are treating as fixed in their one-sector model. CR (2014, note 25, p. 227) also include a tariff revenue term in their expression for welfare in the Armington model, where entry is again fixed. A more general expression for welfare is provided in their online Appendix (equation 21), which allows for entry, although its connection to tariff changes is not explicitly solved for.

We now show that the same intuition can carry through in our setting but only in a very special case: we have to be in the one sector model, that is, when $\alpha = 1$ and all goods are traded; for simplicity we consider the case with no intermediates present, $\gamma = 0$. Otherwise, both losses become first order.[15] The result is stated in the following theorem.

Theorem 2 *Consider an economy near a free trade (FT) equilibrium, $t = 0$ and $\tau > 1$. Restrict attention to the case $\gamma = 0$ (no intermediates). Then for small increases in trade frictions dt and $d\tau$ the formula for welfare changes becomes*

$$\frac{dU^{FT}}{U} \bigg/ \frac{dt}{1+t} = -\frac{\alpha(1-\alpha)}{(\sigma-1)}(1-\lambda_{ii}) \qquad and \qquad \frac{dU^{FT}}{U} \bigg/ \frac{d\tau}{\tau} = -\alpha(1-\lambda_{ii}).$$

Equivalently, in terms of implied changes in the trade share $d\lambda_{ii}/\lambda_i$, we can write:

$$\frac{dU_i/U_i}{d\lambda_{ii}/\lambda_{ii}}^{FT} \bigg|_{d\tau=0} = -\frac{\alpha(1-\alpha)}{\theta\sigma - \sigma + 1} \qquad and \qquad \frac{dU/U}{d\lambda_{ii}/\lambda_{ii}}^{FT} \bigg|_{dt=0} = -\frac{\alpha}{\theta}. \qquad (43)$$

Thus, in the case $\alpha = 1$ (one sector model) welfare losses are of the second order for tariffs since the terms on the left of the above expressions equal 0, and of the first-order for icebergs. In all other cases with $\alpha < 1$, both welfare losses are in general of the first order.

Proof. See Appendix B. ∎

The proof of this theorem comes from solving for all three of the endogenous changes on the right-hand side of (42) in terms of exogenous changes in the *ad valorem* tariff and in iceberg costs, as done in Appendix D. The finding that the welfare cost of changes in the tariff is of the first-order in more realistic settings ($\alpha < 1, \gamma > 0$) demonstrates how the welfare implications of changes in trade frictions in this model can depart from those seen in simpler settings. Note that the first-order effect of tariff changes *must* come from the second term on the right of (42), i.e., the change in entry, since when $\alpha = 1$ then entry is fixed and the first and third terms in (42) still result in a second-order cost of tariffs. This result clearly show that using the formula $-\frac{\alpha}{1-\gamma} \frac{d\lambda_{ii}}{\theta\lambda_{ii}}$ does not capture the welfare gains from trade as we change tariffs in our model.

For illustration, Figure 3 shows how welfare and the domestic share change globally with icebergs and tariffs. The figure considers two simple cases with no

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[15]In Appendix B we characterize the welfare effects in the neighborhood of the free trade equilibrium when $\gamma > 0$. For this case, changes in tariff generate *first-order* welfare losses due to the presence of intermediate goods but this is purely a consequence of the presence of markups.

Figure 3: Welfare effects of tariff and iceberg changes in the one-sector two-sector symmetric model without intermediates
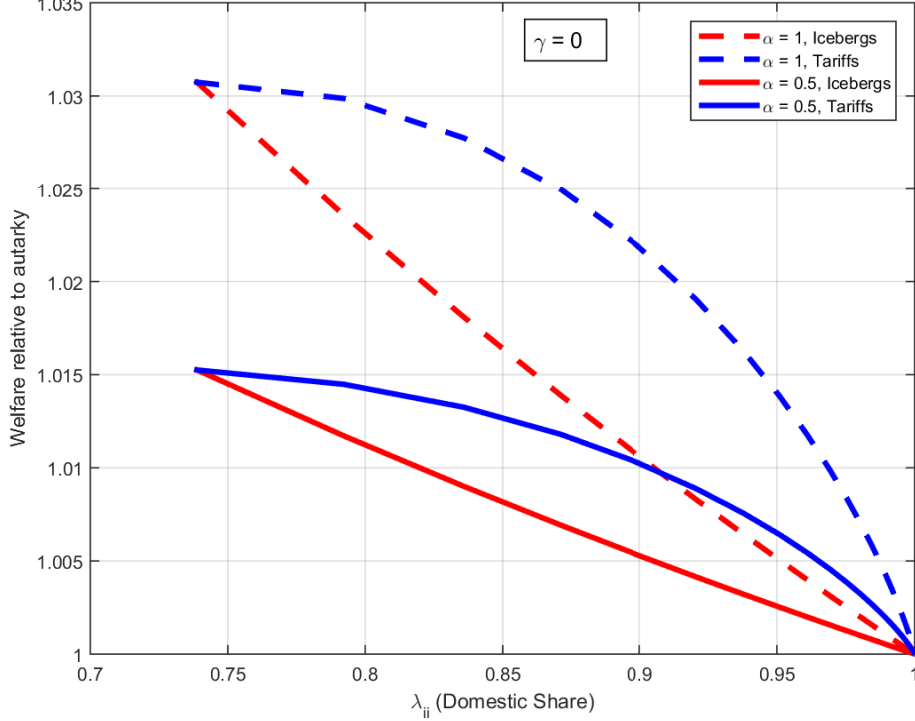
Note: This figure shows how the level of welfare $U = U_i$ (relative to autarky equals 1) and the domestic share $\lambda = \lambda_{ii}$ vary as the tariff $t = t_{ij}$ changes with $t \in (0, \infty)$ and $\tau = \tau_{ij} = 1$ (blue paths) or as the iceberg cost τ changes with $\tau = \tau_{ij} \in (1, \infty)$ and $t = t_{ij} = 0$ (red paths). The dotted lines correspond to $\alpha = 1$ and the solid lines $\alpha = 0.5$. There are no intermediates, $\gamma = 0$. The other model parameters are $\sigma = 5, \theta = 10, f_D = f_{ii} = 1, f_X = f_{ij} = 2$, and $f_i^E = 1$.

intermediate goods ($\gamma = 0$) and in which $\alpha = 1$ or $\alpha = 0.5$. As we can see, near the free trade equilibrium changes in icebergs have always a first order effect on welfare, while for the case of tariff changes this depends on α.

In light of Figure 3, let us now move away from results local to the free-trade equilibrium, and, in search of solutions that apply globally, we solve for the second and third terms on the right of (42) due to changes in *ad valorem* tariffs and in iceberg costs. Here we are interested in determining how and why the welfare change dU_i/U_i can deviate more generally from the expression $-\frac{\alpha}{(1-\gamma)\theta} d\lambda_{ii}/\lambda_{ii}$.

We find that, according the structure of the economy, in some cases $dU_i/U_i > -\frac{\alpha}{(1-\gamma)\theta} d\lambda_{ii}/\lambda_{ii}$ while in others $dU_i/U_i < -\frac{\alpha}{(1-\gamma)\theta} d\lambda_{ii}/\lambda_{ii}$, which can lead to seemingly paradoxical outcomes. To see this, recal that $\Delta < 1$ and that $\theta > \sigma - 1$. Then, the coefficient ξ on the entry term in (42) is guaranteed to be positive if $\Delta < 0$, though it can also be positive for some values of $\Delta > 0$ that are not too

large. If the term is positive, then any increase in entry that accompanies a tariff reduction will *further reduce* the price index in (41) and will *further increase* the resulting welfare gains. The magnitude of this welfare gain is sensitive to the value of γ, which indicates the extent to which the differentiated products are used as intermediate inputs: as γ is larger, just as the gains via trade volumes $(-\frac{\alpha}{1-\gamma}\frac{d\lambda_{ii}}{\theta\lambda_{ii}})$ get larger, so too do the gains from entry correspondingly increase. Linkages boost gains from trade via this channel too.

The welfare impact of a change in the tariff also depends on the change in tariff revenue, the final term on the right of (42). From (26) we obtain imports of $\frac{(1-\lambda_{ii})}{1+t}Y_i$, and then multiplying by the tariff t we obtain tariff revenue $T_i = \frac{t(1-\lambda_{ii})}{1+t}Y_i$. The change in tariff revenue is then

$$\frac{dT_i}{Y_i} = -\frac{td\lambda_{ii}}{1+t} + \left(\frac{1-\lambda_{ii}}{1+t}\right)\frac{dt}{1+t} + \frac{t(1-\lambda_{ii})}{1+t}\frac{dY_i}{Y_i}.$$

Notice that a reduction in the tariff directly lowers tariff revenue in the second term, and also lowers revenue in the third term if gross output Y_i falls, as occurs precisely when $\Delta < 0$. In other words, the same condition that ensures a welfare gain from increased entry in (42) now leads to an offsetting fall in tariff revenue.

Thus, summing the entry and tariff-revenue terms in (42) to get the overall impact on welfare reveals a subtle balance of potential gains and losses in our setting. We pursue this analysis further in Appendix B and, in particular, identify a condition on parameters needed to ensure that $dU_i/U_i > -\frac{\alpha}{(1-\gamma)\theta}d\lambda_{ii}/\lambda_{ii}$, so that the welfare impact of entry due to a tariff reduction leads to an "extra" rise in welfare over and above that attributable to iceberg reductions. These results are summarized as follows.

Theorem 3 *(a) In regions where entry is rising ($dN_i > 0$) due to a reduction in the tariff, a necessary and sufficient condition to have $dU_i/U_i > -\frac{\alpha}{(1-\gamma)\theta}d\lambda_{ii}/\lambda_{ii}$ regardless of the values of $t \geq 0$ and $0 \leq \lambda_{ii} \leq 1$ is that*

$$\tilde{\gamma} \equiv \gamma\left(\frac{\sigma-1}{\sigma}\right) > 1 - \left(\frac{2-\alpha}{\sigma+1-[(\sigma-1)/\theta]}\right) > 0. \tag{44}$$

When entry falls, the same condition implies that $dU_i/U_i < -\frac{\alpha}{(1-\gamma)\theta}d\lambda_{ii}/\lambda_{ii}$.

(b) If $\gamma = 0$ (no intermediate goods) then condition (44) cannot hold, so it follows that $\frac{dU_i}{U_i} \lessgtr -\frac{1}{\theta}\frac{\alpha}{1-\gamma}\frac{d\lambda_{ii}}{\lambda_{ii}}$ as $\frac{dN_i}{N_i} \gtrless 0$

Proof. See Appendix B. ∎

For example, if the differentiated sector has share $\alpha = 0.2$, and $\sigma = \theta = 4$, then condition (44) become $\gamma > 0.77$. If we raise the share α for the differentiated sector to $\alpha = 0.3$, then the condition becomes $\gamma > 0.8$, so intermediate inputs must be even more important. From this we get a clear sense that the differentiated sector subject to the import tariff must be of modest size, while the role of intermediate inputs must be substantial, in order for the increased entry to result in welfare gains larger than $-\frac{\alpha}{(1-\gamma)\theta} d\lambda_{ii}/\lambda_{ii}$. These results reinforce our discussion above, where we found that a higher value of the intermediate share γ leads to greater gains due to entry, but that a low value of α, such as $\alpha < \tilde{\gamma}$ so that $\Delta < 0$, is needed to ensure such entry occurs.

To develop some deeper intuition about welfare impacts, and to explore how the nuanced implications of our model may diverge from prior analyses, we can again turn to numerical simulations. We can then see more clearly how welfare is affected in different configurations of the model and how the conclusions can differ substantially from the results in models without entry.

Figure 4 shows how the level of country welfare U_i and the domestic share λ_{ii} varies either as the tariff level t changes or as the iceberg cost τ varies, over the range from free trade to autarky. Four different cases are studied corresponding to different values of the traded sector share α and the intermediate share γ. The figures may be compared qualitatively: since the model parameters vary widely, the maximal gains from trade differ in each case, and the welfare scale on the vertical axis in not the same in each panel.

A benchmark case is shown in the lower-left panel of the figure, with no non-traded sector as $\alpha = 1$, and a small intermediate share $\gamma = 0.1$. Welfare increases from autarky as we move toward free trade. In the case of pure iceberg costs the gains as we reduce them from prohibitive levels are such that at any given level of the domestic share the gains are lower than when we liberalize pure tariffs costs, and the reason for this is due to the dominant effect of the iceberg costs being lost or wasted; in contrast, tariff revenue is rebate, so higher welfare results. The resulting diagram, like Figure 3, takes on a "rugby ball" shape, with welfare levels identical icebergs and tariffs in the cases of free trade and of autarky, but divergent in between. But as the other three cases in the figure show, this configuration of results is not guaranteed.

Moving from the lower-left to upper-left panel, we increase the intermediate share from $\gamma = 0.1$ to $\gamma = 0.9$. As we know, this stronger input-output linkage in the traded sector can dramatically increase the potential maximal gains from

Figure 4: Welfare effects of tariff and iceberg changes in the two-sector symmetric model
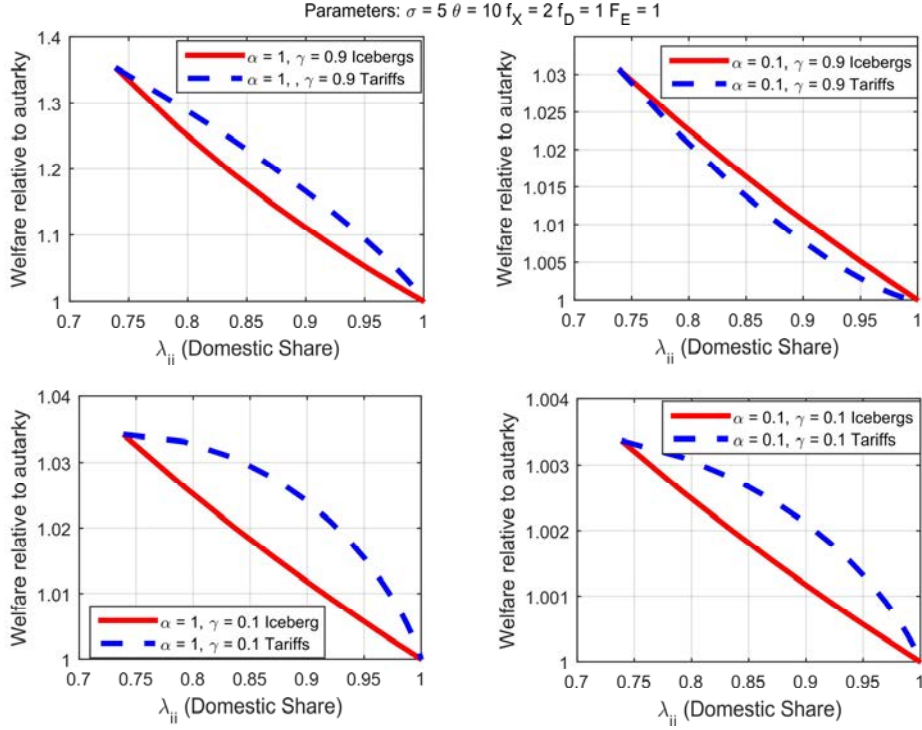
Note: This figure shows how the level of welfare $U = U_i$ (relative to autarky equals 1) and the domestic share $\lambda = \lambda_{ii}$ vary as the tariff $t = t_{ij}$ changes with $t \in (0, \infty)$ and $\tau = \tau_{ij} = 1$ (dotted/blue paths) or as the iceberg cost τ changes with $\tau = \tau_{ij} \in (1, \infty)$ and $t = t_{ij} = 0$ (solid/red paths). The four panels correspond to different values of the nontraded sector share $\alpha \in \{1, 0.1\}$ and the intermediate share $\gamma \in \{0.1, 0.9\}$. The other model parameters are $\sigma = 5, \theta = 10, f_D = f_{ii} = 1, f_X = f_{ij} = 2$, and $f_i^E = 1$.

trade, as is clear from the change in range on the vertical axis (35% versus 3.5%). However, this change also affects the marginal or incremental gains from tariff liberalization or iceberg costs changes in all the equilibria shown. Notice that the "rugby ball" is now much thinner. The slopes of the dotted/blue lines and solid/red lines are now much more similar and this reflects the entry mechanism being more powerfully at work. Close to the free trade equilibrium, the entry effect is positive and this raises the gains from tariff reductions, so the dotted/blue line is therefore steeper, and is closer in slope to the solid/red line. Close to the autarky equilibrium the opposite is true.

Moving from the lower-left to lower-right panel, we decrease the traded sector share from $\alpha = 1$ to $\alpha = 0.1$, and this increase in nontraded share again has the

effect of making the the entry mechanism more powerful once again, and the "rugby ball" is again much thinner. It also, of course, makes the absolute gains from trade smaller in this case as compared to the benchmark (0.3% versus 3.5%).

Finally, moving to the upper-right corner we consider the case where simultaneously both parameter changes occur: we decrease the traded sector share from $\alpha = 1$ to $\alpha = 0.1$ and we increase the intermediate share from $\gamma = 0.1$ to $\gamma = 0.9$. In the four cases in this entire figure, only this case corresponds to the condition in expression (44) being satisfied. Now, compared to the benchmark the effects of entry on welfare are turbocharged, and the result is dramatic. The "rugby ball" flips over completely, and the dotted/blue path (welfare under changing tariffs) sits *below* the solid/red path (welfare under changing icebergs).

Now in this final, perverse case the seemingly intuitive and common-sense qualitative conclusions of more simple trade models, those which lack our entry margin, can potentially be turned upside down. In this case, for a given level of the domestic share, agents would be better off living in a world of iceberg costs (where the costs are totally wasted) than in a world of tariffs (where tariff revenue is rebated). This is because the effect of tariffs, when levied on revenue cost, not production cost, can distort the entry decision so much—under particular but potentially realistic configurations with both large nontraded sectors and large intermediate shares—that the welfare losses in the iceberg case end up smaller than in the tariff case. Putting this finding another way, if such a world is more realistic, then the gains from tariff liberalization can be much, much larger than we might have previously thought when using models without entry.

5 Data Description

Our goal is to quantify the effects of actual tariff reductions over the last quarter century. In order to do so, we need detailed information on tariff changes as well as on production and trade flows for a large set of countries. In particular, we are interested on understanding how developed and developing countries are impacted by changes in trade policy and this can only be done if the data cover both set of countries. We start by first describing the sources and the way we obtain tariff data and later on move to explain the source for production and trade flow data.

5.1 New Tariff Data

This study builds a new comprehensive annual tariff dataset for the early 1980s on. We obtain tariff schedules from five primary sources: (i) raw tariff schedules from the TRAINS and IDB databases accessed via the World Bank's WITS website as far back as 1988 for some countries; (ii) manually collected tariff schedules published by the International Customs Tariffs Bureau (BITD), some dating back as far as the 1950s;[16] (iii) U.S. tariff schedules from the U.S. International Trade Commission from 1989 onwards (Feenstra, Romalis, and Schott 2002); (iv) U.S. tariff schedules derived from detailed U.S. tariff revenue and trade data from 1974 to 1988 maintained by the Center for International Data at UC Davis; and (v) the texts of preferential trade agreements primarily sourced from the WTO's website, the World Bank's Global Preferential Trade Agreements Database, or the Tuck Center for International Business Trade Agreements Database. For the U.S., specific tariffs have been converted into *ad valorem* tariffs by dividing by the average unit value of matching imported products. Due to the difficulties of extracting specific tariff information for other countries and matching it to appropriate unit values, only the *ad valorem* component of their tariffs are used. The vast majority of tariffs are *ad valorem*. Switzerland is a key exception here, with tariffs being specific. We proxy Swiss tariffs with tariffs of another EFTA member (Norway). We aggregate MFN and each non-MFN tariff program to the 4-digit SITC Revision 2 level by taking the simple average of tariff lines within each SITC code.[17]

Tariff schedules are often not available in each year, especially for smaller countries. Updated schedules are more likely to be available after significant tariff changes. Rather than replacing "missing" MFN tariffs by linearly interpolating observations, missing observations are set equal to the nearest preceding observation. If there is no preceding observation, missing MFN tariffs are set equal to the nearest observation. Missing non-MFN tariff data (other than punitive tariffs applied in a handful of bilateral relationships) are more difficult to construct for two reasons: (i) they are often not published in a given tariff schedule; and (ii) preferential trade agreements have often been phased in. To address this we researched the text of over 100 regional trade agreements and Generalized System of Prefer-

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[16]Most tariff schedules can be fairly readily matched to the SITC classification.

[17]Multiple preferential tariffs may be applicable for trade in a particular product between two countries. Since the most favorable one may change over time, we keep track of each potentially applicable tariff program.

ences (GSP) programs to ascertain the start date of each agreement or program and how the typical tariff preference was phased in. To simplify our construction of missing preferential tariffs we express observed preferential tariffs as a fraction of the applicable MFN tariff. We fill in missing values of this fraction based on information on how the tariff preferences were phased in. Preferential tariffs are then constructed as the product of this fraction and the MFN tariff. We keep the most favorable potentially applicable preferential tariff. Punitive non-MFN tariff levels tend not to change over time (though the countries they apply to do change). We replace missing observations in the same way we replace missing MFN tariff observations.

An overview of the new tariff data is presented in Figures 5 to 9. These data show, with country coverage and disaggregated detail of a kind we have have never seen before, the remarkable impacts of the Uruguay Round on the levels and dispersion of tariff rates around the world from the 1980s to the 2010s.

To start, Figure 5 plots the average (mean) *ad valorem* tariff rates, both MFN and Preferential, across all countries and all goods at the SITC 4-digit goods level, in each year from 1984 to 2011, for the full sample, the Advanced economies, and the Emerging and Developing economies. At the start of the period shown, in the 1980s, the typical sample size for the calculations of these statistics is about 1 million distinct tariff lines. By the late 2000s, at the end of the period shown, the sample size in a given year is well over 2 million distinct tariff lines. It is clear that both types of tariffs fell over the period, by about 9 percentage points, with essentially all of the reductions concentrated after 1990.

Given the similar trends, we focus henceforth on MFN tariffs in this section. Figure 6 plots the median MFN *ad valorem* tariff rate across all goods at the SITC 4-digit level, in each year, for the full sample, the Advanced economies and the Emerging and Developing economies. It also plots ten percentiles from 5th, 15th, 25th, . . . to 95th in each year to give an idea of the dispersion of tariff rates. This figure shows very clearly that the Uruguay Round was followed by a dramatic reduction in both the levels and dispersion of tariff rates, with these trends being particularly concentrated in the subsample of Emerging and Developing economies. In part this reflects the fact that these countries started with higher levels and dispersion to begin with, and so had more scope for these kinds of policy adjustments. In contrast, the Advanced countries had made much greater progress in this direction during earlier GATT rounds going back to the 1940s.

Figure 7 uses histograms and kernel density plots to show the distributions of

Figure 5: Average MFN and Preferential *ad valorem* tariff rates
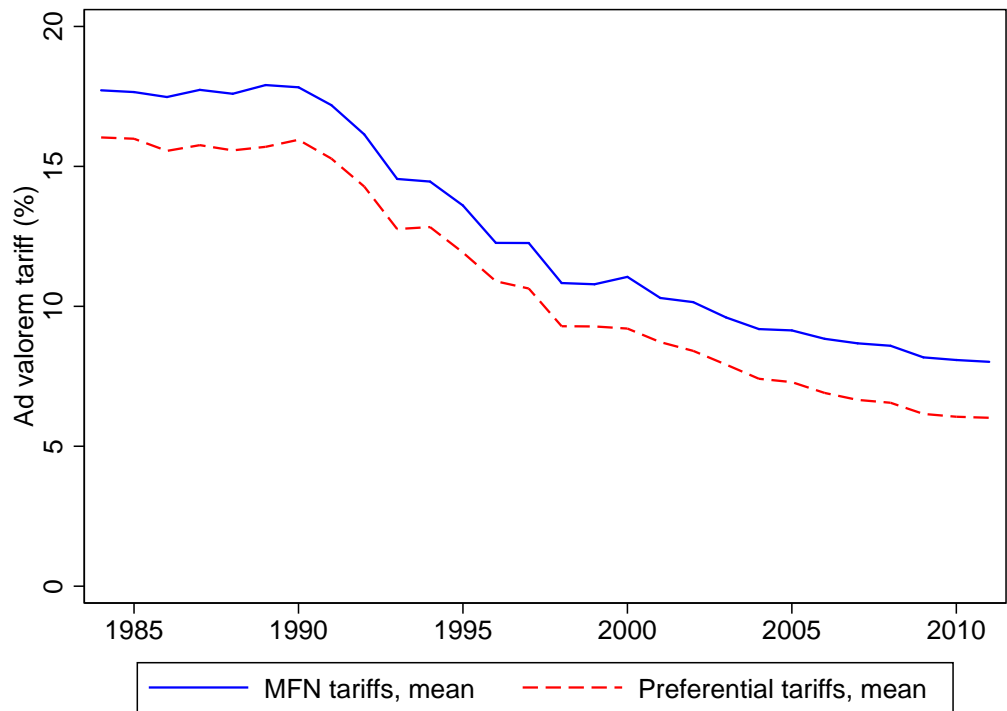
Note: Averages are taken over all 4-digit SITC level good, all countries, by year 1984–2011.

ad valorem tariff rates across countries and goods, for two snapshot years that we will use for our policy experiments: a pre-Uruguay 1990 sample year and a post-Uruguay 2010 sample year. The histograms are truncated at the 50% tariff level; a small number of tariffs over this level (some well over 100%) appear in both sample years for a few unusual goods and countries, but this right tail is not very representative. Within the range shown, tariff peaks at certain round numbers are clearly visible (0, 5, 10, 15, etc.), as one would expect. However, looking past those peaks, we can clearly see again the impacts of changes in tariff policy over this period. The spike at zero rises, as more zero-tariff rates appear across goods and countries, and in the strictly positive region mass is shifted from the above-20% region and into the below-20% region.

Finally, Figures 8 and 9 provides sectoral detail for tariffs aggregated up to the level of 10 tradable sectors which we use in our calibrated model. This figure shows clearly that the Uruguay Round did not have a peculiar compositional impact across sectors. It lowered average tariffs pretty much across the board in all sectors, and was not just confined to some limited areas of the tradable

Figure 6: Distributions of MFN *ad valorem* tariff rates
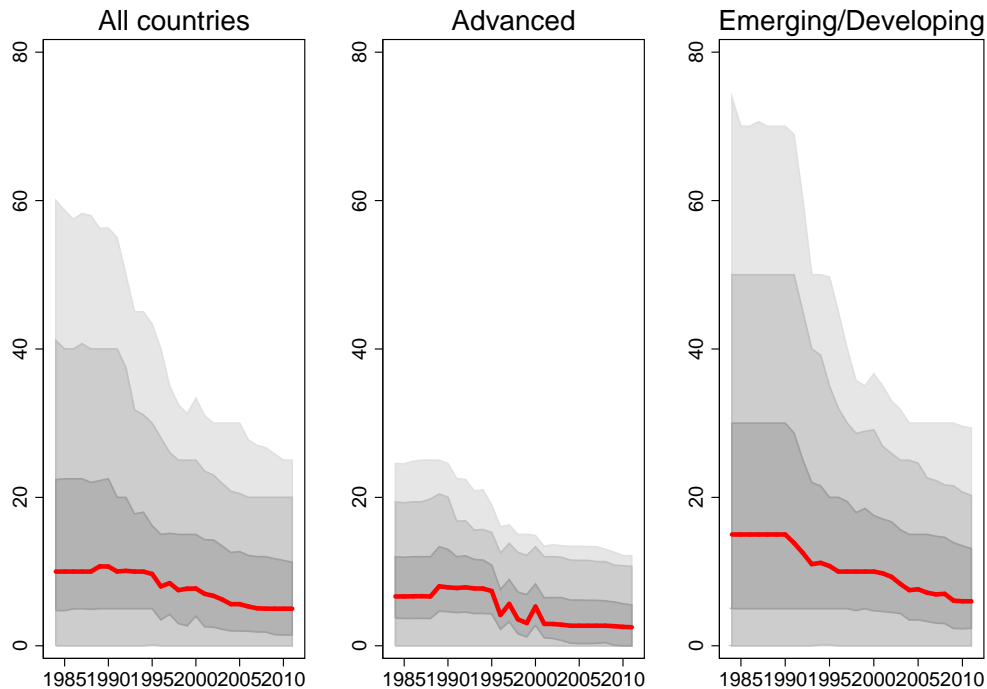
Note: We use data for all 4-digit SITC level good, in 3 samples, by year 1984–2011 (percentiles 5/10/25/50/75/90/95).

economy. And again, the figure clearly shows the much larger scope for tariff reductions in the Emerging and Developing sample, given the relatively high tariff rates they had at the start of the period in all sectors as compared to the Advanced economies.

5.2 Production and Trade Data

To obtain production and trade data, we relied on the Eora MRIO multi-region IO database. This dataset, to our knowledge, is the most comprehensive dataset available that contains information on production, trade flows and input–output (IO) tables for 189 countries.[18] Six sources are used to construct the multi-region IO table. The sources are are: 1) input–output tables and production data from national statistical offices, 2) IO from Eurostat, IDE-JETRO, and OECD, 3) the UN National Accounts Main Aggregates Database, 4) the UN National Accounts Official Data, 5) the UN Comtrade international trade database, and 6) the UN

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[18]Please refer to http://worldmrio.com/ for more information.

Figure 7: Distributions of MFN *ad valorem* tariff rates, 4-digit SITC goods, all countries, in 1990 and 2010

Observations in 1990 = 1,119,930. Observations in 2010 = 2,724,754. Truncated to values <=50.
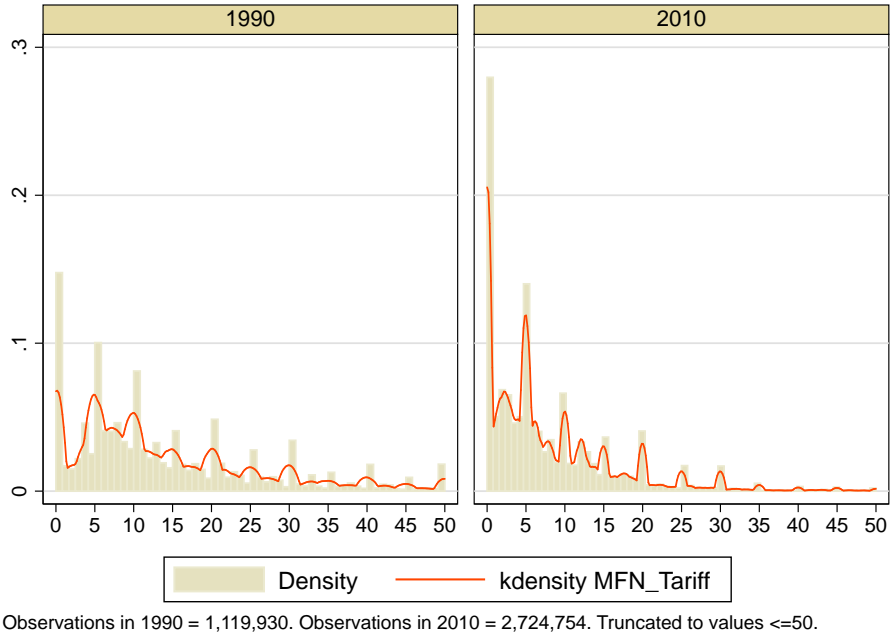
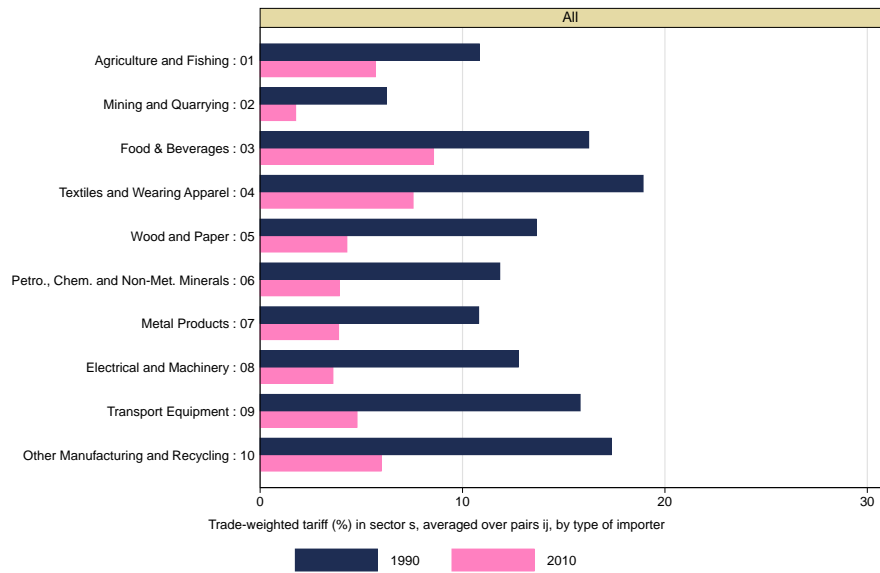Figure 8: MFN *ad valorem* tariff rates, 10 sectors, all countries, in 1990 and 2010
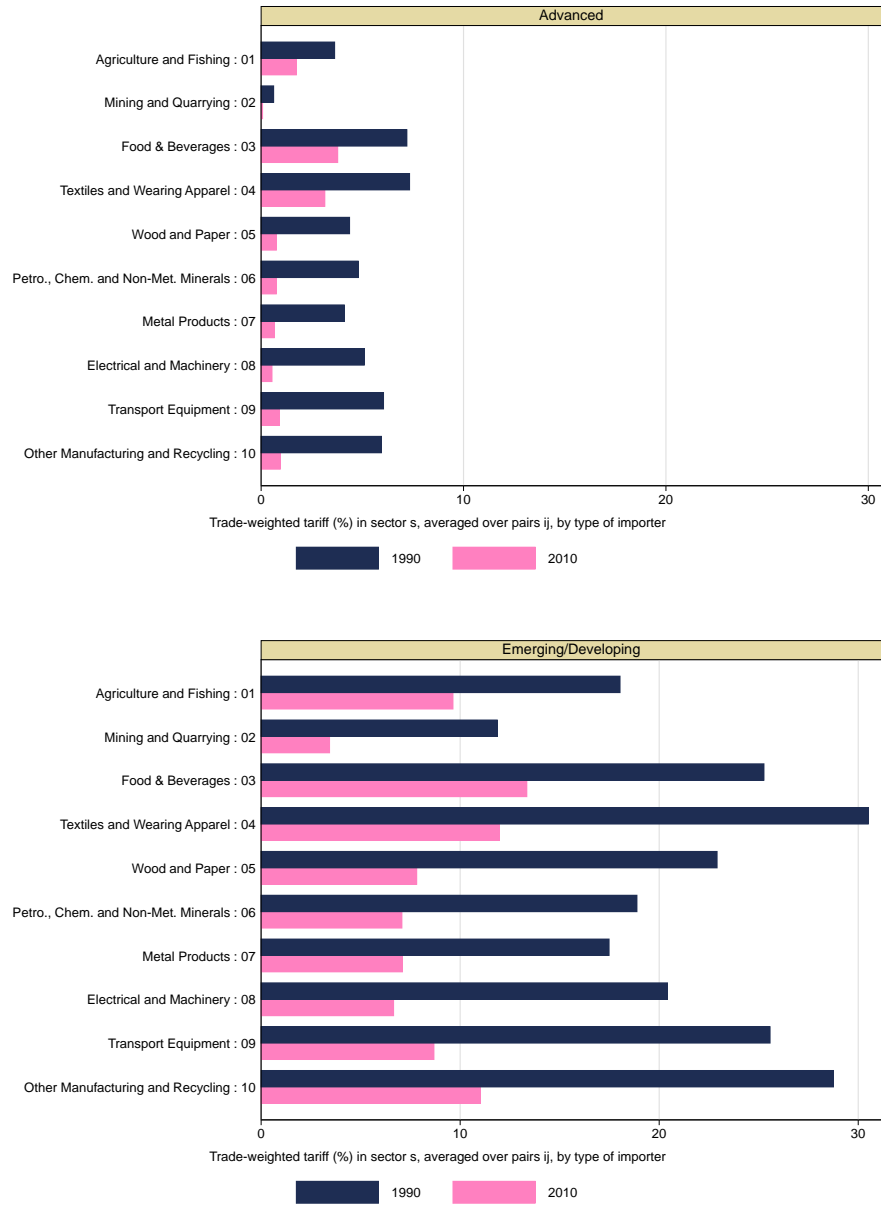
Figure 9: MFN *ad valorem* tariff rates, 10 sectors, all countries, in 1990 and 2010

Servicetrade international trade database. For further information, refer to Lenzen et al. (2012, 2013). We use Eora to obtain data on value added shares ($\gamma_{i,s}$), share of intermediate inputs in production ($\gamma_{i,s's}$), gross output ($GO_{i,s}$), and total exports ($E_{i,s}$).

A key advantage of this database, compared to others, is the fact that it contains information for a large set of countries (develop and developing countries) and for early years. In particular we use the 1990 multi-region table with 25-sector harmonized classifications. As a reference point, in comparison with the WIOD database, we have more than three times the number of countries and account for a number of developing countries, some of them quite small. Moreover, there is no WIOD for the year 1990, the period immediately before the Uruguay Round tariff cuts. Having data for the 90's allows us to take the model to the data and evaluate the effects of every single tariff reform after that period.

With our new tariff data we have greatly increased the disaggregation of the trade and tariff data, however, from 13 aggregate merchandise sectors to 800 disaggregate SITC goods. This increase in the number of countries and traded goods has come at the cost of aggregating the sectors to only about one-half as many as included in the WIOD, and in particular, have only five broad nontraded service sectors. We view this aggregation of the nontraded services as quite harmless to our question of studying the impact of the Uruguay Round tariff cuts. The large number of countries and very large number of traded goods raises the question, however, of how we solve the model: that would be a formidable task if all goods were treated as distinct industries. Instead, we argue in the next sections that it is possible to *consistently aggregate* over the traded goods at the SITC level to obtain aggregate tariffs.

6 Taking the Quantitative Model to the Data

There are two issues that we need to deal in order to take the model to the data. First, we need to find a way to infer a large set of unobservable parameters.[19] Second, we need to deal with the fact that trade is imbalanced and that our static model cannot accommodate this. The way we solve the first issue is by expressing the equilibrium conditions of the model in relative changes. By doing so, this

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[19]Several parameters from our model are directly observable, like value added shares and input-output coefficients. However, there are a large number of parameters, like fixed entry, production, and exports costs, that are not observed. Yet, we will show how to solve the model without needing to estimate fixed costs.

allows us to condition on an observed allocation in a given base year and solve the model without needing estimates of fixed costs and other parameters which are not directly observable.[20] The way we solve the second issue is by first calibrating the model with trade deficits as a residual and then use the model to net out the deficits.

6.1 Equilibrium conditions of the model in relative form

To gain traction with the model when taking it to the data, we express the equilibrium conditions in relative terms using hat notation for the ratio of after-versus-before levels for a given perturbation. After a lot of tedious manipulation (see Appendix C) one can show that the corresponding equilibrium conditions of the model are given by

$$\widehat{x}_{i,s} \equiv (\widehat{w}_i)^{\gamma_{i,s}} \prod_{s'=1}^{S} \left(\widehat{\widetilde{P}}_{i,s'}\right)^{\gamma_{i,s's}}, \tag{45}$$

$$\widehat{\widetilde{P}}_{i,s} = \left(\sum_{j=1}^{M} \lambda_{ji,s} \left[\widehat{\tau}_{ji,s}\widehat{x}_{j,s}\widehat{(1+t_{ji,s})}\right]^{-\theta_s} \hat{A}_{ji,s}\right)^{\frac{1}{-\theta_s}}, \tag{46}$$

$$\hat{\lambda}_{ji,s} = \left[\frac{\widehat{\tau}_{ji,s}\widehat{x}_{j,s}\widehat{(1+t_{ji,s})}}{\widehat{\widetilde{P}}_{i,s}}\right]^{-\theta_s} \hat{A}_{ji,s'} \tag{47}$$

$$Y'_{i,s} = \sum_{s'=1}^{S} \tilde{\gamma}_{i,ss'} \sum_{j=1}^{M} \frac{\lambda'_{ij,s'}}{1+t'_{ij,s'}} Y'_{j,s'} + \alpha_{i,s}\left(w'_i L'_i + T'_i\right), \tag{48}$$

$$\sum_{s=1}^{S}\sum_{j=1}^{M} \frac{\lambda'_{ji,s}}{1+t'_{ji,s}} Y'_{i,s} = \sum_{s=1}^{S}\sum_{j=1}^{M} \frac{\lambda'_{ij,s}}{1+t'_{ij,s}} Y'_{j,s'} \tag{49}$$

$$\hat{N}_{i,s} = \frac{\sum_{j=1}^{M} \widehat{\frac{\lambda_{ij,s}}{1+t_{ij,s}}} Y_{j,s}}{\widehat{w}_i}, \tag{50}$$

where

$$\hat{A}_{ji,s} \equiv \hat{N}_{j,s} \left(\frac{\widehat{w}_j\widehat{(1+t_{ji,s})}}{\hat{Y}_{i,s}}\right)^{\frac{\sigma_s-1-\theta_s}{\sigma_s-1}} \quad \text{and} \quad T'_i = \sum_{s=1}^{S}\sum_{j\neq i} \frac{t'_{ji,s}}{1+t'_{ji,s}} \lambda_{ji,s} Y'_{i,s'}; \ \tilde{\gamma}_{i,ss'} \equiv \gamma_{i,ss'} \frac{\sigma_s-1}{\sigma_s}.$$

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[20]This idea was first advanced by Dekle, Eaton, and Kortum (2008) in the context of a Ricardian trade model. CP and Ossa (2014) show that one can use this method to analyze the effects of tariff policy. CR refer to this as the exact hat algebra and show how it works for a variety of trade models, including a multi-county, multi-industry Melitz model similar to the one we use here. The key difference is that they show how it works for the case of cost tariffs while we use it for the case of revenue tariffs.

Table 2: Elasticities

Sector(s)	$\frac{\sigma_s \theta_s}{\sigma_s - 1} - 1$	θ_s	σ_s
Agriculture and Fishing (1 sector)	9.11	8.6	6.7
Mining and Quarrying (1 sector)	13.53	13.0	9.7
Manufacturing Sectors (all 8 sectors)	5.55	5.1	4.4
Nontraded services (all 5 sectors)	—	2.7	2.8

As we can see, by expressing the model in this way we can analyze the effects of tariff changes without needing information of fixed entry and operating costs which are, in general, difficult to estimate in the data, especially at the necessary disaggregation. The only identification restriction we will impose is that these fixed have not changed over time.

The above system of equations can then be used to study the impact of a change in iceberg costs, $\widehat{\tau}_{ji,s}$, as well as tariffs $\left(\widehat{1 + t_{ji,s}}\right)$.

6.2 Trade Elasticity

We need to specify how we obtain estimates the elasticity of substitution and the Pareto parameter. We use CP's estimate of the trade elasticity. They show that by triple differencing the gravity equation one can identify the elasticities using tariff policy variation. In the context of our model the elasticity that is estimated is given by $1 - \frac{\sigma_s \theta_s}{\sigma_s - 1}$.

In order to separately identify θ_s from σ_s we rely on estimates from the literature to obtain $\frac{\theta_s}{\sigma_s - 1}$. The two most used studies to deal with this issue are Chaney (2008) and Eaton, Kortum, and Kramarz (2011). Chaney (2008) obtains the coefficient by regressing the log of the rank of US firms according to their sales in the United States on the log of sales using Compustat data on US listed firms. Eaton, Kortum, and Kramarz (2011) who use a different procedure and data on the propensity of French firms to export to multiple markets. Chaney (2008) finds that $\frac{\theta_s}{\sigma_s - 1} \approx 2$, while Eaton, Kortum, and Kramarz (2011) find $\frac{\theta_s}{\sigma_s - 1} \approx 1.5$. We take this latter estimate and apply it to our sectoral elasticities estimated using CP. For the case of services we use a value of $\sigma_s = 2.8$

The values for the elasticities that we obtain are presented in Table 2. Note that these values imply that σ_s are 6.7, 9.7, and 4.4 respectively. These numbers are clearly within the range of values estimated by Broda and Weinstein (2006)

where they find that the simple average of the elasticity of substitution are 17 at a seven-digit (TSUSA), 7 at the three-digit (TSUSA), 12 at a ten-digit (HTS) and 4 at a three-digit (HTS) goods disaggregation.

6.3 Tariff aggregation, expenditure and final goods shares

Finally, using the information on tariffs, trade flows, production and with the estimated trade elasticities we can now solve for the model domestic sales, expenditure shares and final good shares.

6.3.1 Domestic Sales

To calculate domestic sales ($E_{ii,s}$) by country and sector, we need data on gross production ($GO_{i,s}$), and total exports ($E_{i,s} \equiv \sum_{j \neq i} E_{ij,s} = \sum_{j \neq i} \frac{\lambda_{ij,s}}{1+t_{ij,s}} Y_{j,s}$). Recall that gross production in sector s is given by $\frac{\sigma_s - 1}{\sigma_s} \sum_{j=1}^{M} \frac{\lambda_{ij,s}}{1+t_{ij,s}} Y_{j,s}$. We want to solve for $E_{ii,s} = \lambda_{ii,s} Y_{i,s}$. Therefore, domestic sales are given by

$$E_{ii,s} = \frac{\sigma_s}{\sigma_s - 1} GO_{i,s} - E_{i,s}.$$

6.3.2 Expenditure Shares

Denote by $Y_{ij,s}$ the total expenditure of country j on sector s goods from country i. Total expenditure includes tariffs, therefore in order to calculate $Y_{ij,s}$ we take imports and multiply by tariffs. We do this at the sectoral level, namely $Y_{ij,s} = E_{ij,s} (1 + t_{ij,s})$. Note that $Y_{ii,s} = E_{ii,s}$. We then calculate expenditure shares as

$$\lambda_{ij,s} = Y_{ij,s} / \sum_i Y_{ij,s}, \tag{51}$$

where $\sum_i Y_{ij,s} = Y_{j,s}$ is total expenditure.

6.3.3 Final goods consumption shares

To calculate final consumption share, $\alpha_{i,s}$ we take the total expenditure of sector s goods, subtract the intermediate goods expenditure and divide by total final absorption. Namely

$$\alpha_{i,s} = \frac{Y_{i,s} - \sum_{s'=1}^{S} \gamma_{i,ss'} GO_{i,s'}}{w_i L_i + T_i},$$

where $w_i L_i$ is total value added and T_i tariff revenue which we calculate as $T_i = \sum_{s=1}^{S} \sum_{j \neq i} t_{ji,s} E_{ji,s}$.

6.3.4 Tariff aggregation from the good level

An important task is to find a model consistent procedure to aggregate goods-level tariffs at a fine level to the correct sectoral-level equivalent at a coarser level.

We make the assumption that in country j and sector s there are $G_{j,s}$ goods indexed by g. Our goal is to solve for a sectoral tariff $t_{ji,s}$ such that the change in this sectoral tariff $(1 + t_{ji,s})$ is equivalent to the effect of the *observed* changes in tariffs at a goods level $1 + t_{ji,s}(g)$, $g = 1..., G_{j,s}$.

We calculate $\lambda_{ij,s}(g)$, namely the expenditure share on g goods as

$$\lambda_{ij,s}(g) = E_{ij,s}(g)\left(1 + t_{ij,s}(g)\right) / \sum_i Y_{ij,s}. \tag{52}$$

Note that the expenditure share from country i on all $G_{i,s}$ goods from country j has to equal to the total expenditure on sector s goods from country j, therefore

$$\sum_{g=1}^{G_{j,s}} \lambda_{ji,s}(g) = \lambda_{ji,s}.$$

Then the trade balance condition (27) can be re-written by adding the summation over goods g as

$$\sum_{s=1}^{S} \sum_{j \neq i} \sum_{g=1}^{G_{j,s}} \frac{\lambda_{ji,s}(g)}{1 + t_{ji,s}(g)} Y_{i,s} = \sum_{s=1}^{S} \sum_{j \neq i} \sum_{g=1}^{G_{i,s}} \frac{\lambda_{ij,s}(g)}{1 + t_{ij,s}(g)} Y_{j,s}. \tag{53}$$

In order for (53) to be equivalent to (27), it is apparent that the tariffs must satisfy

$$\frac{\lambda_{ji,s}}{1 + t_{ji,s}} \equiv \sum_{g=1}^{G_{j,s}} \frac{\lambda_{ji,s}(g)}{1 + t_{ji,s}(g)}. \tag{54}$$

Using (51), (52) and some manipulation we obtain a tariff aggregation formula:

$$\left(1 + t_{ji,s}\right) = \frac{\sum\limits_{g=1}^{G_{j,s}} E_{ji,s}(g)\left(1 + t_{ji,s}(g)\right)}{\sum\limits_{g=1}^{G_{j,s}} E_{ji,s}(g)} \quad \Longleftrightarrow \quad t_{ji,s} = \frac{\sum\limits_{g=1}^{G_{j,s}} E_{ji,s}(g) t_{ji,s}(g)}{\sum\limits_{g=1}^{G_{j,s}} E_{ji,s}(g)} \tag{55}$$

In other words, when aggregating over a finer set of goods g to a coarse sector

level, the sectoral aggregate tariff factor $1 + t_{ji,s}$ should be computed as a trade-weighted mean of the tariff factors across the various goods g. The analogous condition must hold for computing $1 + t'_{ji,s}$ in the new equilibrium, evaluating the shares $\lambda'_{ji,s}(g)/\lambda'_{ji,s}$ in this new equilibrium. Clearly, if there is a *uniform* change in the goods-level tariffs $1 + t_{ji,s}(g)$ then the new shares would equal their initial values $\lambda_{ji,s}(g)/\lambda_{ji,s}$, and in that case it is obvious from the above that the change in $1 + t_{ji,s}(g)$ would equal the change in $1 + t_{ji,s}$, i.e., the change in the sectoral tariff just equals the uniform change in the goods-level tariffs.

7   A Quantitative Assessment of the Uruguay Round

In this section we evaluate the trade, entry, and welfare effects of the observed change in trade policy over the years 1990 to 2010.

We take as our initial baseline is the levels of tariffs in the year 1990, the year before tariffs started falling as a consequence of the Uruguay Round. We will then aim to quantify the economic effects of tariff changes by performing three different exercises, as follows.

- We first impose on the model the actual changes in MFN tariffs from the year 1990 to the year 2010, holding fixed the preferential tariffs (PTA) in place in the year 1990. This exercise we think of as informative on the effects of changes due to multilateral negotiations, so we label this case the "Uruguay Round" experiment.[21]

- We then go beyond the Uruguay Round effects on MFN tariffs, and aim to quantify the effects from all tariff changes, MFN together with any preferential PTA tariffs in place in the year 2010. We refer to this last exercise as the "Uruguay Round + Preference" experiment.

- Finally, we explore whether there are any extra gains from tariff changes by moving to a world with zero tariffs, what we refer as the "Free Trade" experiment.

We then compare the gains between these three exercises, namely the gains from Uruguay Round, Uruguay Round + Preference, and Free Trade.

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[21]Specifically, we set the 2010 tariff equal to minimum of the 1990 preference tariff and the 2010 MFN tariff.

Figure 10: Trade effects from tariff changes, world, histograms, 1990–2010
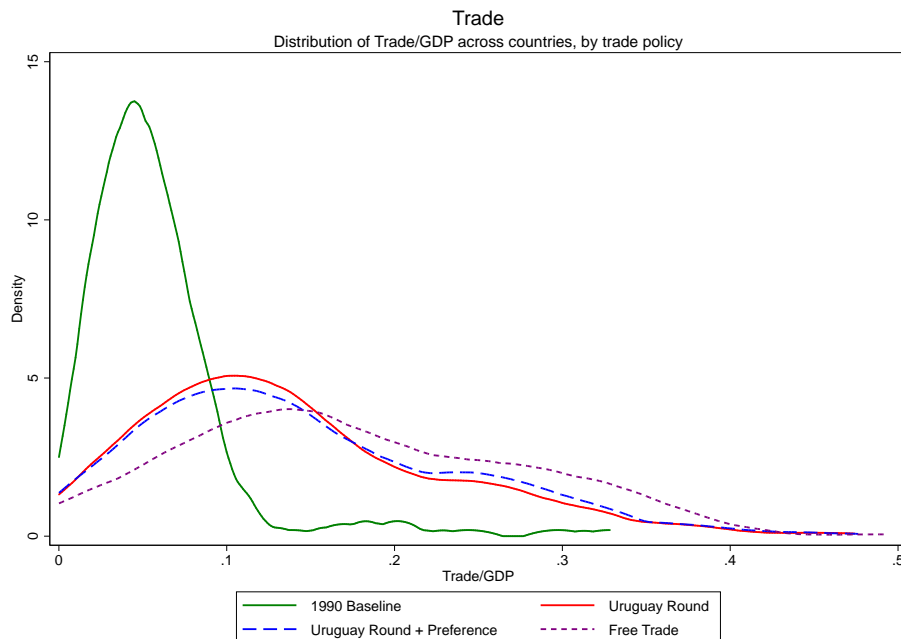
We first start by showing the trade effects from the change in tariffs from our three experiments. We calculate the share of total expenditure in each country on foreign goods, a model counterpart of the trade share of GDP. Figure 10 uses smooth histograms, or kernel density plots, to show the effects on the trade share of GDP in all countries in the world in the baseline and 3 experiments. The results are stark, Uruguay Round tariff reductions generate considerable trade effects. The distribution of trade shares in 1990 had its mass concentrated in the 0%–10% region. After the Uruguay Round experiment this mass is more spread out in the 0%–20% region. There is little difference between the three experiments, suggesting that most of the impact that could have been achieved by a move towards free trade was achieved by the Uruguay Round experiment; still, the Free Trade case shows some extra trade might be generated by the removal of all tariffs.

Figure 11 shows the effects on the trade share of GDP for the case of Advanced and Emerging countries. The results are stark, Uruguay Round tariff reductions generate considerable trade effects. The world, on average, became more open with a roughly twofold increase in the median trade share in both subsamples. Interestingly, the median level of openness increases slightly more for Advanced economies relative to Emerging and Developing economies. The trade effects for

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Figure 11: Trade effects from tariff changes, subsamples, detail, 1990–2010
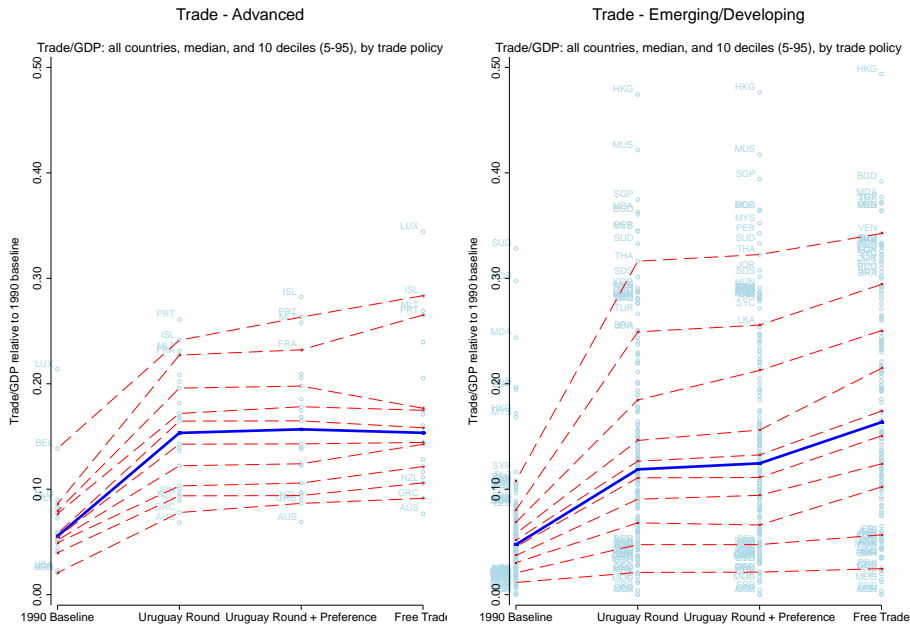
the latter are very dispersed. Some countries, like Hong Kong and Singapore display a substantial increase in trade share, even from an initial high level, while for other countries the trade share remain almost constant.

The second takeaway from both of figures is that Uruguay Round + Preference does not generate a large increase in world trade relative to Uruguay Round only. This is clearly seen by comparing the median change in openness for Advanced and Emerging and Developing countries as we move from the Uruguay Round case to the Uruguay Round + PTA. The line is flat, as it is at almost all marked deciles. The histogram makes the same point. Finally, note that moving to zero tariffs generates considerable trade share effects for Emerging economies, but little in the way of extra trade share effects for Advanced economies. This result unmasks the asymmetrical impact of further reducing tariffs for Emerging and Developing countries. However, as we will see soon, this extra increase in trade may not generate substantial positive welfare effects, unlike the Uruguay Round.

We now discuss our findings on firm entry. Figure 12 presents the distribution of changes in entry across all countries and sectors by trade policy relative to the 1990 baseline (normalized to 1). Concretely, we are showing the change in entry, namely $\hat{N}_{i,s}$. The histogram in Figure 12 shows that the entry margin is very active

Figure 12: Entry effects from tariff changes, world, histograms, 1990–2010

Entry
Distribution of entry across countries/sectors, by trade policy

Truncated to [0.5,1.5]
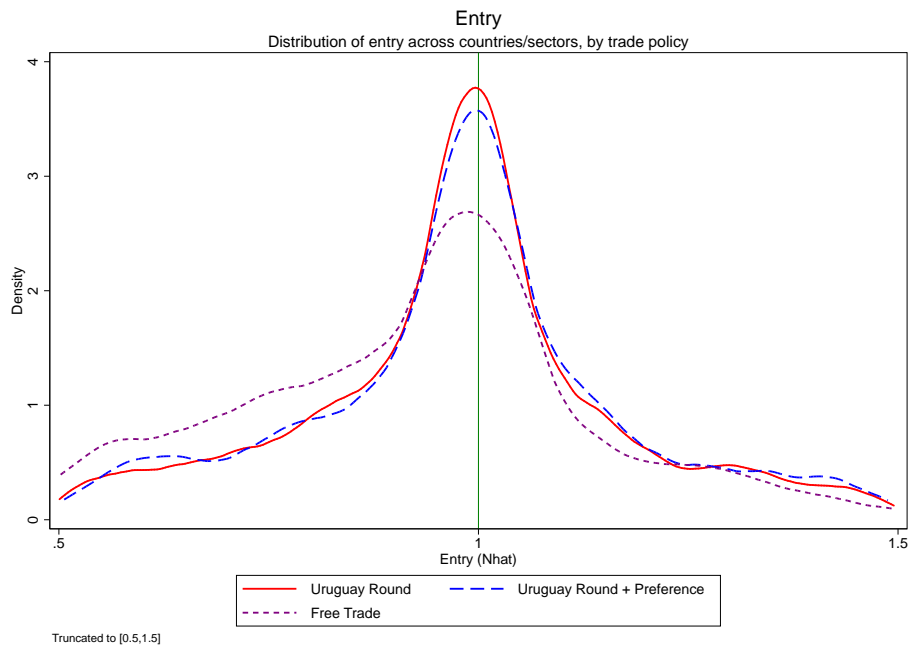
and heavily impacted by the changes in tariffs. As we can see, there is mass in both tails reflecting that in some country-sector cases entry goes up, while in others it falls. As we compare experiments it is evident that both Uruguay Round and Uruguay Round + Preference generate very similar entry effects, while moving to Free trade affects entry a little bit more. In particular, it tends to reduce entry on average, in part, as a consequence of increased import competition.
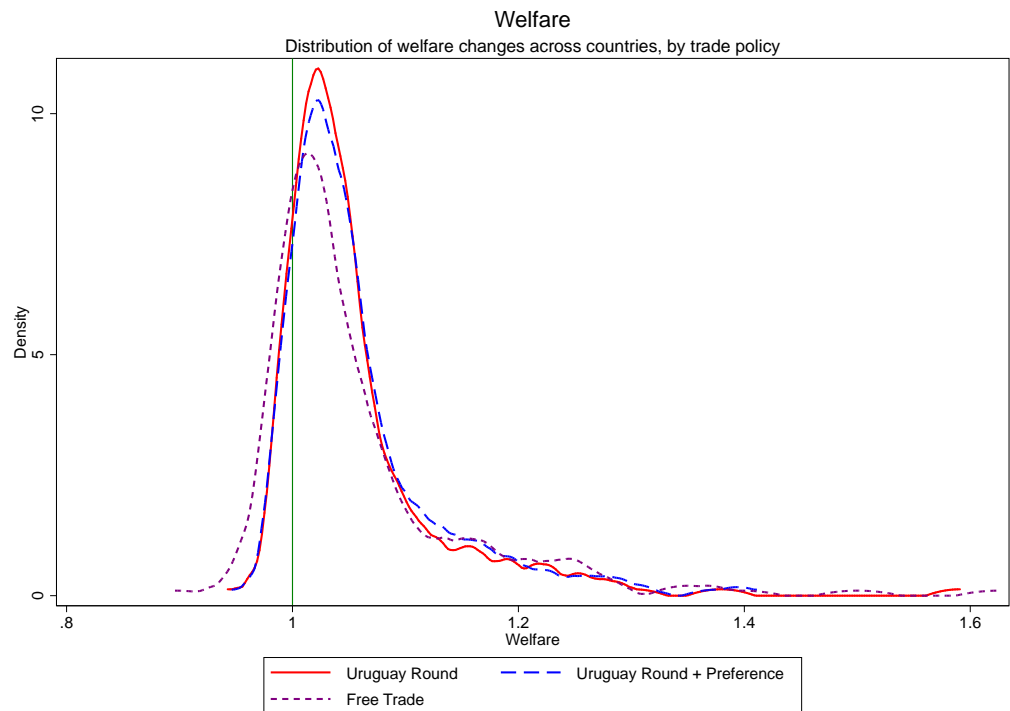
Figure 13 separates the distribution of entry effects in the Advanced versus Emerging and Developing countries. The left hand side panel shows the distribution of the change in entry for Advanced economies while the right hand side panel presents the distribution of the change in entry for Emerging markets. As we can see, trade policy impacts firm entry across these types of countries in very different ways. In particular, we find that firm entry reacts more in Advanced economies (where tariff changes were smaller) relative to Emerging economies (where tariff changes were bigger): for all three experiments the results on firm entry are very concentrated for Emerging markets while this is not the case for Advanced economies. These results show clearly that entry is impacted by tariffs not only theoretically, as we discussed several times in the paper, but that it is also affected in a quantitatively significant way to a change in trade policy.

Figure 13: Entry effects from tariff changes, subsamples, histograms, 1990–2010
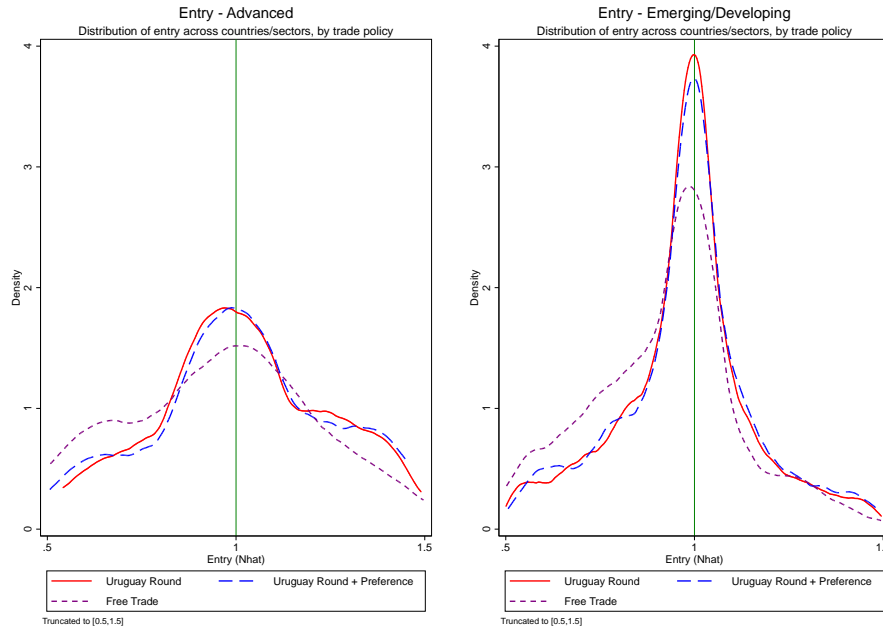
Figures 14 and 15 presents the welfare effects for the world, namely the change in welfare relative to the base year 1990 (normalized to 1) for each of our three experiments. Here, the Uruguay Round accounts for most of the welfare effects from tariff changes, with little further difference made by the other two experiments. In fact, the average gains across countries in our sample are +5.6% for the Uruguay Round, +5.9% for Uruguay Round + Preference, and +5.9% for Free trade. Yet there is substantial heterogeneity in terms of winners and losers, as the histogram makes very clear, even if most countries are winners. And if anything, the distribution of welfare changes shifts slightly left under Free Trade relative to Uruguay Round, at least below the median, indicating that in our model the move to zero tariffs and full free trade might have little welfare upside and quite a bit of downside. The bottom line here is that there may be little additional welfare gain from a move towards zero tariffs from the position we find ourselves in after the Uruguay Round, and which built on the previous 40 years of GATT-driven tariff reductions which started after 1945. These findings are reinforced when we split the sample according to Advanced and Emerging economies, as we can see in Figure 16.

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Figure 14: Welfare effects from tariff changes, world, histograms, 1990–2010

Welfare
Distribution of welfare changes across countries, by trade policy

—— Uruguay Round	– – – Uruguay Round + Preference	
---- Free Trade		

8   Conclusion

In this paper we study the trade, firm entry, and welfare effects arising from actual changes in trade policy in the last two decades. We do so with a multi-sector heterogeneous firm model that incorporates tariffs, traded intermediate goods, and an input-output structure that is realistic for modern economies.

First, we show that trade policy impacts firm entry and exit, a channel that has not been fully explored before. We provide a theoretical characterization of the conditions under which tariffs affect firm entry and, ultimately, welfare. We show that in a range of models the forces driving firm entry are inoperative only under restrictive assumptions about the tradability of goods, the production structure, or the way tariffs are modeled.

Next, we present a new comprehensive annual tariff dataset starting in the 1980s that allows us to measure how MFN and PTA tariffs have changed over time at a very disaggregated level. With these new data we can perform trade policy experiments which could not be explored before now, something that we leave for future research.

Figure 15: Welfare effects from tariff changes, world, detail, 1990–2010

Welfare
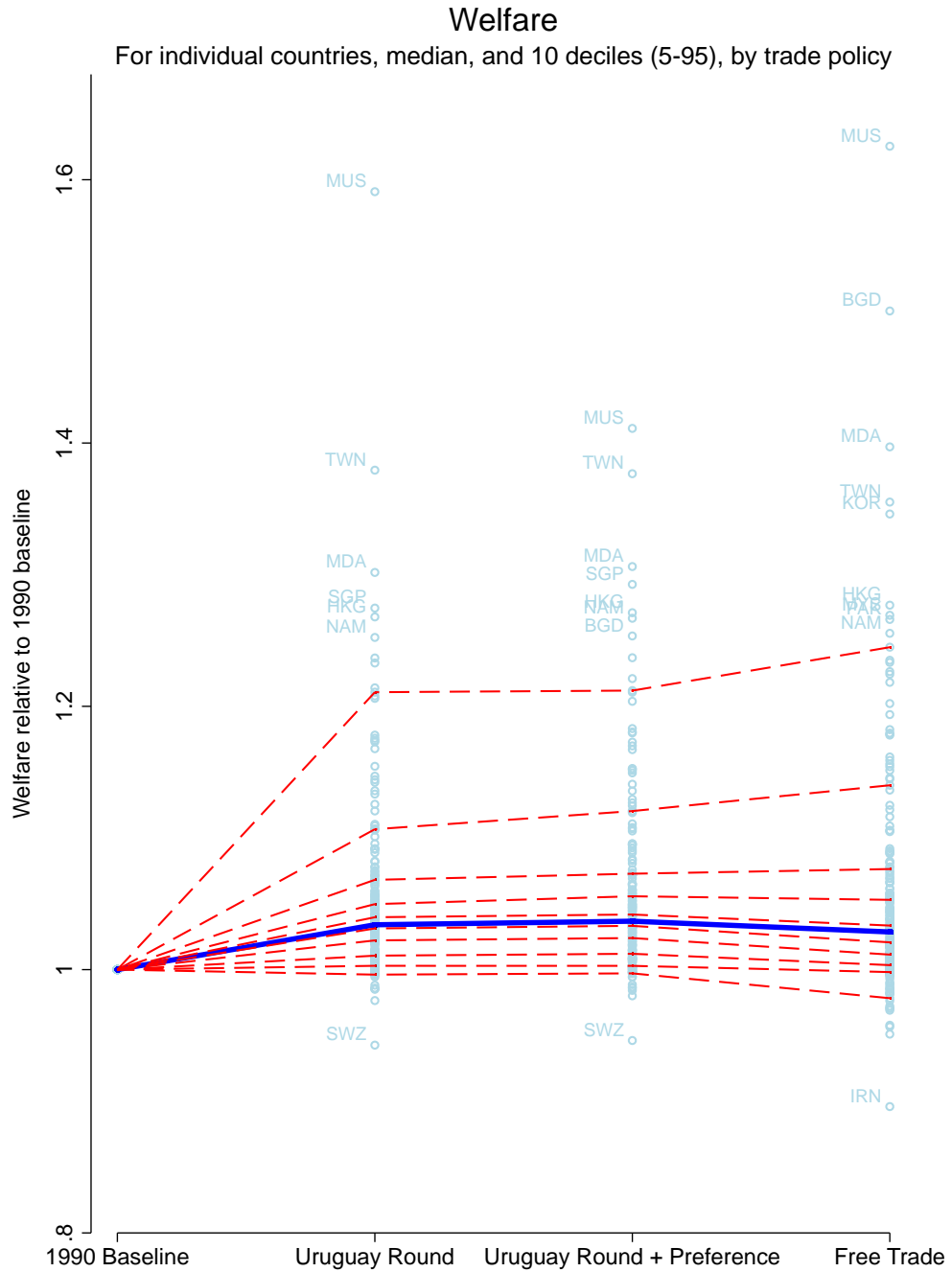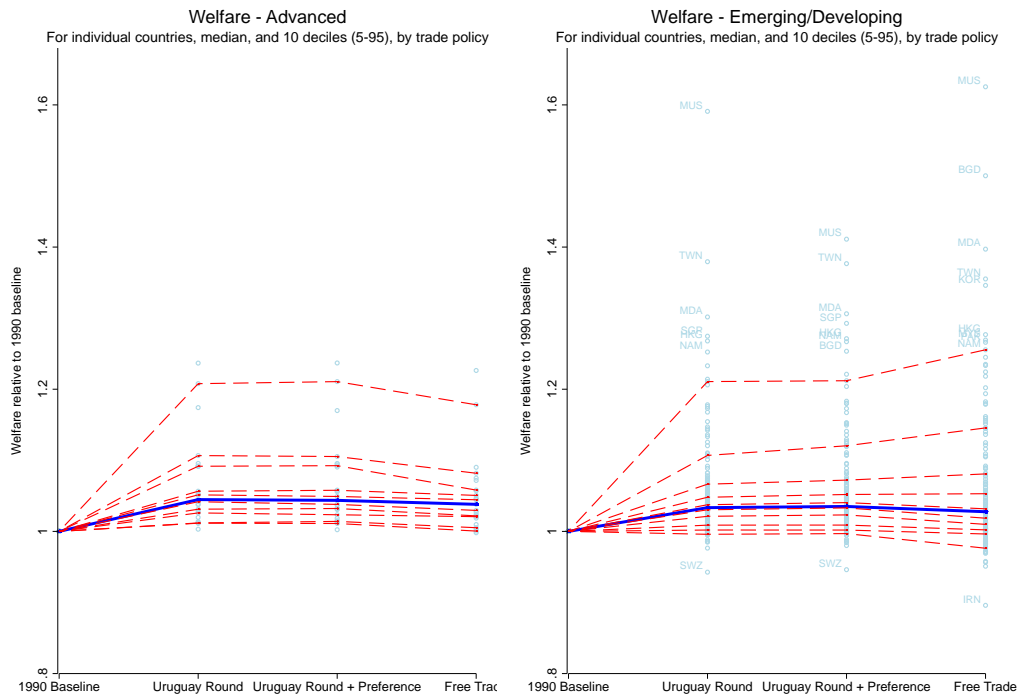For individual countries, median, and 10 deciles (5-95), by trade policy

Figure 16: Welfare effects from tariff changes, subsamples, detail, 1990–2010

Finally, with our model and our data, we then go beyond gains-from-trade estimates based largely on advanced economies, and use an 189-country, 15-sector version of our model to quantify the effects of trade liberalization over the period 1990–2010, including the greatest round of global tariff elimination, the Uruguay Round. We find that the actual reductions in MFN tariffs in this period generated large trade, entry, and welfare effects. We also find that the effects from preferential tariff reductions have not contributed much to total world trade and welfare, and that gains from future liberalization may remain on the table only for some developing countries.

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A Cost and revenue tariffs with and without rebate

A.1 Cost tariffs

Consider first the case cost tariffs. In a slight abuse of notation as compared to the main text, we denote the solution to problem (1) by

$$\pi_{ij}(\varphi) = \tilde{p}_{ij}(\varphi)\tilde{q}_{ij}(\varphi) - \frac{w_i\tau_{ij}(1+t_{ij})\tilde{q}_{ij}(\varphi)}{\varphi} - w_i f_{ij}, \tag{56}$$

where $\tilde{q}_{ij}$ is the quantity chosen by consumers at the optimal price

$$\tilde{p}_{ij}(\varphi) = \left(\frac{\sigma}{\sigma-1}\right)\frac{w_i\tau_{ij}(1+t_{ij})}{\varphi}. \tag{57}$$

Defining the expected value of firm revenues by $\tilde{R}_i$, and the expected revenues per entrant from country j by $\tilde{R}_{ij}$, we have

$$\tilde{R}_i \equiv \sum_{j=1}^{M} N_i \tilde{R}_{ij} \equiv \sum_{j=1}^{M} N_i \int_{\varphi_{ij}^*}^{\infty} \tilde{p}_{ij}(\varphi)\tilde{q}_{ij}(\varphi)\, dG(\varphi),$$

where φ_{ij}^* is the cutoff productivity at which $\pi_{ij}(\varphi_{ij}^*) = 0$. As in the main text, we assume a Pareto distribution, $G(\varphi) = 1 - \varphi^{-\theta}$, for the firm productivities, with $\varphi \geq 1$. We also assume CES demand with elasticity σ, which implies that $\tilde{q}_{ij}(\varphi) = \tilde{q}_{ij}\left(\varphi_{ij}^*\right)\left(\varphi/\varphi_{ij}^*\right)^{\sigma}$. Then combining the above equations, we obtain

$$
\begin{aligned}
\tilde{R}_i &= \sum_{j=1}^{M} N_i \int_{\varphi_{ij}^*}^{\infty} \left(\frac{\sigma}{\sigma-1}\right)\frac{w_i\tau_{ij}(1+t_{ij})}{\varphi}\tilde{q}_{ij}\left(\varphi_{ij}^*\right)\left(\frac{\varphi}{\varphi_{ij}^*}\right)^{\sigma}\theta\varphi^{-\theta-1}d\varphi \\
&= \sum_{j=1}^{M} N_i \left(\frac{\theta\sigma}{\sigma-1}\right)\frac{w_i\tau_{ij}(1+t_{ij})\tilde{q}_{ij}\left(\varphi_{ij}^*\right)}{\varphi_{ij}^*}\int_{\varphi_{ij}^*}^{\infty}\frac{\varphi^{\sigma-\theta-2}}{(\varphi_{ij}^*)^{\sigma-1}}d\varphi \\
&= \left(\frac{\theta\sigma}{\sigma-1}\right)\sum_{j=1}^{M} N_i \frac{w_i\tau_{ij}(1+t_{ij})\tilde{q}_{ij}\left(\varphi_{ij}^*\right)}{\varphi_{ij}^*(\sigma-\theta-1)}\left.\frac{\varphi^{\sigma-\theta-1}}{(\varphi_{ij}^*)^{\sigma-1}}\right|_{\varphi_{ij}^*}^{\infty} \\
&= \left(\frac{\theta\sigma}{\sigma-1}\right)\sum_{j=1}^{M} N_i \frac{w_i\tau_{ij}(1+t_{ij})\tilde{q}_{ij}\left(\varphi_{ij}^*\right)}{\varphi_{ij}^*(\theta-\sigma+1)}(\varphi_{ij}^*)^{-\theta} \\
&= \left(\frac{\theta\sigma}{\theta-\sigma+1}\right)\sum_{j=1}^{M} N_i w_i f_{ij}(\varphi_{ij}^*)^{-\theta}, \tag{58}
\end{aligned}
$$

where we assume $\theta > \sigma - 1$ and the last line follows from $\pi_{ij}(\varphi_{ij}^*) = 0$ in (56).

In an analogous fashion, defining the expected value of firm profits by $\tilde{\Pi}_i$, and the expected profits per entrant from country j by $\tilde{\Pi}_{ij}$, we have

$$\Pi_i \equiv \sum_{j=1}^{M} N_i \Pi_{ij} \equiv \sum_{j=1}^{M} N_i \int_{\varphi_{ij}^*}^{\infty} \left\{ \left[\tilde{p}_{ij}(\varphi) - \frac{w_i \tau_{ij}(1 + t_{ij})}{\varphi} \right] \tilde{q}_{ij}(\varphi) - w_i f_{ij} \right\} dG(\varphi)$$

$$= \sum_{j=1}^{M} N_i \int_{\varphi_{ij}^*}^{\infty} \left\{ \left(\frac{1}{\sigma - 1} \right) \frac{w_i \tau_{ij}(1 + t_{ij})}{\varphi} \tilde{q}_{ij}(\varphi) - w_i f_{ij} \right\} dG(\varphi),$$

where the second line follows by using (57). Using the above equations, we obtain

$$\Pi_i = \sum_{j=1}^{M} N_i \int_{\varphi_{ij}^*}^{\infty} \left\{ \frac{w_i \tau_{ij}(1 + t_{ij}) \tilde{q}_{ij}\left(\varphi_{ij}^*\right)}{(\sigma - 1)\varphi} \left(\frac{\varphi}{\varphi_{ij}^*} \right)^{\sigma} - w_i f_{ij} \right\} \theta \varphi^{-\theta - 1} d\varphi$$

$$= \sum_{j=1}^{M} N_i \left(\frac{\theta}{\sigma - 1} \right) \frac{w_i \tau_{ij}(1 + t_{ij}) \tilde{q}_{ij}\left(\varphi_{ij}^*\right)}{\varphi_{ij}^*(\sigma - \theta - 1)} \frac{\varphi^{\sigma - \theta - 1}}{(\varphi_{ij}^*)^{\sigma - 1}} + w_i f_{ij} \varphi^{-\theta} \Bigg|_{\varphi_{ij}^*}^{\infty}$$

$$= \left(\frac{\theta}{\sigma - 1} \right) \sum_{j=1}^{M} N_i \frac{w_i \tau_{ij}(1 + t_{ij}) \tilde{q}_{ij}\left(\varphi_{ij}^*\right)}{\varphi_{ij}^*(\theta - \sigma + 1)} (\varphi_{ij}^*)^{-\theta} - w_i f_{ij}(\varphi_{ij}^*)^{-\theta}$$

$$= \left[\left(\frac{\theta}{\sigma - 1} \right) - 1 \right] \sum_{j=1}^{M} N_i w_i f_{ij}(\varphi_{ij}^*)^{-\theta}$$

$$= \left(\frac{\sigma - 1}{\theta - \sigma + 1} \right) \sum_{j=1}^{M} N_i w_i f_{ij}(\varphi_{ij}^*)^{-\theta}, \tag{59}$$

where the second-to-last line follows again from $\pi_{ij}(\varphi_{ij}^*) = 0$ in (56).

By combining these results we obtain

$$\Pi_i = \frac{\sigma - 1}{\sigma \theta} \tilde{R}_i. \tag{60}$$

Free entry then implies

$$\Pi_i = N_i w_i f_i^E, \tag{61}$$

and therefore the mass of entrants is given by

$$N_i = \frac{\sigma - 1}{\sigma \theta} \frac{\tilde{R}_i}{w_i f_i^E}. \tag{62}$$

Given that $\tilde{R}_i = Y_i$, we get that the mass of entrants is given by

$$N_i = \frac{\sigma - 1}{\sigma \theta} \frac{Y_i}{w_i f_i^E}. \tag{63}$$

A.1.1 Entry with tariff revenue rebate

Consider the case in which tariff revenue is rebated to consumers. In this case

$$Y_i = w_i L_i + T_i, \tag{64}$$

and therefore, we get that entry is given by

$$N_i = \frac{\sigma - 1}{\sigma \theta} \frac{1}{w_i f_i^E} (w_i L_i + T_i). \tag{65}$$

A.1.2 Entry without tariff revenue rebate

Consider the case in which tariff revenue is not rebated to consumers (consumed by the government, i.e., disposed), then

$$Y_i = w_i L_i, \tag{66}$$

and then entry is fixed and given by

$$N_i = \frac{\sigma - 1}{\sigma \theta} \frac{1}{f_i^E} L_i. \tag{67}$$

A.2 Revenue tariffs

Now consider the case of revenue tariffs. Again in a slight abuse of notation as compared to the main text, we denote the solution to problem (4) by

$$\pi_{ij}(\varphi) = p_{ij}(\varphi) \tilde{q}_{ij}(\varphi) - \frac{w_i \tau_{ij} \tilde{q}_{ij}(\varphi)}{\varphi} - f_{ij}, \tag{68}$$

where the optimal price charged by the firm to consumers is still as shown in (57), while the firm earns $p_{ij}(\varphi) = \tilde{p}_{ij}(\varphi) / (1 + t_{ij})$.

Defining the expected value of firm revenues at the net-of-tariff price by R_i, and the expected revenues at the net-of-tariff price per entrant from country j by R_{ij}, we have

$$R_i \equiv \sum_{j=1}^{M} N_i R_{ij} \equiv \sum_{j=1}^{M} N_i \int_{\varphi_{ij}^*}^{\infty} p_{ij}(\varphi) \tilde{q}_{ij}(\varphi) dG(\varphi),$$

where φ_{ij}^* is the cutoff productivity at which $\pi_{ij}(\varphi_{ij}^*) = 0$ in (68). This cutoff can differ from that obtained from $\pi_{ij}(\varphi_{ij}^*) = 0$ in (56). Combining the above equations, we obtain

$$
\begin{aligned}
R_i &= \sum_{j=1}^{M} N_i \int_{\varphi_{ij}^*}^{\infty} \left(\frac{\sigma}{\sigma - 1} \right) \frac{w_i \tau_{ij}}{\varphi} \tilde{q}_{ij}\left(\varphi_{ij}^*\right) \left(\frac{\varphi}{\varphi_{ij}^*} \right)^{\sigma} \theta \varphi^{-\theta - 1} d\varphi \\
&= \left(\frac{\theta \sigma}{\sigma - 1} \right) \sum_{j=1}^{M} N_i \frac{w_i \tau_{ij} \tilde{q}_{ij}\left(\varphi_{ij}^*\right)}{\varphi_{ij}^*(\theta - \sigma + 1)} (\varphi_{ij}^*)^{-\theta} \\
&= \left(\frac{\theta \sigma}{\theta - \sigma + 1} \right) \sum_{j=1}^{M} N_i w_i f_{ij} (\varphi_{ij}^*)^{-\theta}, \tag{69}
\end{aligned}
$$

where the intermediate steps are analogous to those shown in (58), but without the cost tariff $(1 + t_{ij})$ that appears there, and once again the last line follows from $\pi_{ij}(\varphi_{ij}^*) = 0$ in (68).

We can also define expected profits in this case as

$$
\begin{aligned}
\Pi_i \equiv \sum_{j=1}^{M} N_i \Pi_{ij} &\equiv \sum_{j=1}^{M} N_i \int_{\varphi_{ij}^*}^{\infty} \left\{ \left[p_{ij}(\varphi) - \frac{w_i \tau_{ij}}{\varphi} \right] \tilde{q}_{ij}(\varphi) - w_i f_{ij} \right\} dG(\varphi) \\
&= \sum_{j=1}^{M} N_i \int_{\varphi_{ij}^*}^{\infty} \left\{ \left(\frac{1}{\sigma - 1} \right) \frac{w_i \tau_{ij}}{\varphi} \tilde{q}_{ij}(\varphi) - w_i f_{ij} \right\} dG(\varphi),
\end{aligned}
$$

where the second line follows by using (57) with $p_{ij}(\varphi) = \tilde{p}_{ij}(\varphi) / (1 + t_{ij})$. Using the above equations, we obtain

$$
\begin{aligned}
\Pi_i &= \sum_{j=1}^{M} N_i \int_{\varphi_{ij}^*}^{\infty} \left\{ \frac{w_i \tau_{ij} \tilde{q}_{ij}\left(\varphi_{ij}^*\right)}{(\sigma - 1)\varphi} \left(\frac{\varphi}{\varphi_{ij}^*} \right)^{\sigma} - w_i f_{ij} \right\} \theta \varphi^{-\theta-1} d\varphi \\
&= \left(\frac{\sigma - 1}{\theta - \sigma + 1} \right) \sum_{j=1}^{M} N_i w_i f_{ij} (\varphi_{ij}^*)^{-\theta},
\end{aligned}
\tag{70}
$$

where once again the intermediate steps are analogous to those in (59), but without the cost tariff $(1 + t_{ij})$ that appears there, and we use $\pi_{ij}(\varphi_{ij}^*) = 0$ from (68).

By combining the definition of Π_i and R_i, we obtain

$$
\Pi_i = \frac{\sigma - 1}{\sigma \theta} R_i.
\tag{71}
$$

Free entry then implies

$$
\Pi_i = N_i w_i f_i^E,
\tag{72}
$$

and therefore the mass of entrants is defined by

$$
N_i = \frac{\sigma - 1}{\sigma \theta} \frac{R_i}{w_i f_i^E}.
\tag{73}
$$

Then entry is given by

$$
N_i = \frac{\sigma - 1}{\sigma \theta} \frac{1}{w_i f_i^E} (Y_i - T_i).
\tag{74}
$$

A.2.1 Entry with tariff revenue rebate

Consider the case in which tariff revenue is rebated to consumers. In this case

$$
Y_i = w_i L_i + T_i,
\tag{75}
$$

and therefore, we get that entry is fixed

$$N_i = \frac{\sigma - 1}{\sigma \theta} \frac{L_i}{f_i^E}. \tag{76}$$

A.2.2 Entry without tariff revenue rebate

Consider the case in which tariff revenue is not rebated to consumers (consumed by the government, i.e. disposed), then

$$Y_i = w_i L_i, \tag{77}$$

and then entry is given by

$$N_i = \frac{\sigma - 1}{\sigma \theta} \frac{1}{w_i f_i^E} (w_i L_i - T_i). \tag{78}$$

B Symmetric, two-sector, two-country equilibrium

In the main body of the text we present a closed-form solution for the comparative statics of a two sector model. These equilibrium conditions are obtained assuming that countries are identical. One of the sectors has traded intermediate inputs and makes a nontraded "manufacture" good that is consumed and also used as an intermediate input domestically. The second sector is consists of a nontraded final "service" good produced with labor and consumed by households. We normalize the price of this good to one and this ensures that $w = 1$. The taste share of the service good is given by $1 - \alpha$, while the manufacture sector (the one with traded intermediates) has a taste share of α. We let $\gamma \equiv \gamma_{i,ss}$ denote the single term in the input-output matrix for the first sector in each country, with $0 < \gamma < 1$. We denote by $\tilde{\gamma} = \frac{\sigma - 1}{\sigma} \gamma$. We assume that the *ad valorem* tariffs (i.e., revenue tariffs) are equal across countries, $t_{ij} = t$ for $i \neq j$, while $t_{ii} = 0$, and the same assumption for iceberg costs $\tau_{ij} = \tau$ for $i \neq j$, while $\tau_{ii} = 1$. We also assume that fixed costs are equal across countries $f_{ii} = f_{jj} = f_D$, $f_{ij} = f_{ji} = f_X$, $f_i^E = f_j^E = f^E$.

To simplify the notation we denote by Y_i, $\tilde{P}_i$, λ_{ii} the expenditure, price index, and expenditure share in country i of sector one goods. By symmetry we can further simplify to repress subscripts, and define $Y_i = Y_j \equiv Y$, $\tilde{P}_i = \tilde{P}_j \equiv \check{P}$, $\lambda_{ii} = \lambda_{jj} \equiv \lambda$, $\lambda_{ij} = \lambda_{ji} \equiv 1 - \lambda$, $N_i = N_j \equiv N$, $\varphi_{ii}^* = \bar{\varphi}_{ii} \equiv \varphi_D^*$, and $\varphi_{ij}^* = \varphi_{ji}^* \equiv \varphi_X^*$.

The equilibrium conditions for this model are then as follows

$$\varphi_D^* = \left(\frac{\sigma}{\sigma - 1} \right) \left(\frac{\sigma f_D}{Y} \right)^{\frac{1}{\sigma - 1}} \frac{1}{\left(\tilde{P} \right)^{1 - \gamma}}, \tag{79}$$

$$\varphi_X^* = \left(\frac{\sigma}{\sigma - 1} \right) \left(\frac{\sigma f_X}{Y} \right)^{\frac{1}{\sigma - 1}} \frac{\tau (1 + t)^{\frac{\sigma}{\sigma - 1}}}{\left(\tilde{P} \right)^{1 - \gamma}}, \tag{80}$$

$$f_D \varphi_D^{* - \theta} + f_X \varphi_X^{* - \theta} = \frac{\theta - \sigma + 1}{\sigma - 1} f^E, \tag{81}$$

$$Y \left(1 - \tilde{\gamma} \frac{1 + \lambda t}{1 + t} - \alpha \frac{t (1 - \lambda)}{1 + t} \right) = \alpha w L, \tag{82}$$

58

$$\tilde{P} = \left(\varphi_D^{*-\theta} N \left(\frac{\sigma}{\sigma - 1} \frac{\tilde{P}^{\gamma}}{\tilde{\varphi}_D} \right)^{1-\sigma} + \bar{\varphi}_X^{-\theta} N \left(\frac{\sigma}{\sigma - 1} \frac{\tilde{P}^{\gamma} \tau (1 + t)}{\tilde{\varphi}_X} \right)^{1-\sigma} \right)^{\frac{1}{1-\sigma}}, \tag{83}$$

$$\lambda = \varphi_D^{*-\theta} N \left(\frac{\sigma}{\sigma - 1} \frac{1}{(\tilde{P})^{1-\gamma} \tilde{\varphi}_D} \right)^{1-\sigma}, \tag{84}$$

where $\tilde{\varphi}_j = \varphi_j^* \left(\frac{1}{\theta + 1 - \sigma} \right)^{\frac{1}{\sigma - 1}}$ for $j = \{D, X\}$.

The endogenous variables to solve for are $\varphi_D^*, \varphi_X^*, P, Y, \lambda$, and N. We now proceed to show how to solve for all these variables as a function of trade costs.

From (79) and (80) we can solve for φ_X^* as a function of φ_D^*,

$$\varphi_X^* = \tilde{F}(\tau, t) \varphi_D^*, \tag{85}$$

where $\tilde{F}(\tau, t) = (f_X / f_D)^{\frac{1}{\sigma - 1}} \tau (1 + t)^{\frac{\sigma}{\sigma - 1}}$. Note that in order to have an equilibrium with $\varphi_X^* > \varphi_D^*$ we assume $f_X > f_D$ which implies that $\tilde{F}(\tau, t) > 1$. Using this last condition together with equilibrium condition (81) we can solve uniquely for $\varphi_D^*(\tau, t)$ as a function of parameters and trade costs,

$$\varphi_D^*(\tau, t) = \left(\frac{\theta - \sigma + 1}{\sigma - 1} \right)^{-\frac{1}{\theta}} \left(\frac{f^E}{f_D + f_X \tilde{F}(\tau, t)^{-\theta}} \right)^{-\frac{1}{\theta}}, \tag{86}$$

from which the solution for $\varphi_X^*(\tau, t)$ follows immediately from (85).

After obtaining these two expressions for the entry thresholds we can solve for prices as a function of the mass of entrants using equilibrium condition (83),

$$\tilde{P}^{1-\gamma} = N^{\frac{1}{(1-\sigma)}} G(\tau, t), \tag{87}$$

where

$$G(\tau, t) = \frac{\sigma}{\sigma - 1} \left(\varphi_D^*(\tau, t)^{-\theta} \left(\frac{1}{\tilde{\varphi}_D} \right)^{1-\sigma} + \varphi_X^*(\tau, t)^{-\theta} \left(\frac{\tau (1 + t)}{\tilde{\varphi}_X} \right)^{1-\sigma} \right)^{\frac{1}{1-\sigma}},$$

and $\varphi_X^*(\tau, t) = \tilde{F}(\tau, t) \varphi_D^*(\tau, t)$.

We can then solve for λ using (84), and (87)

$$\lambda = \varphi_D^*(\tau, t)^{-\theta} \left(\frac{\sigma}{\sigma - 1} \frac{1}{G(\tau, t) \tilde{\varphi}_D(\tau, t)} \right)^{1-\sigma},$$

and after some algebra we obtain $\lambda(\tau, t)$, that is to say, an expression for λ only as a function of parameters and trade costs (τ, t),

$$\lambda(\tau, t) = \frac{1}{1 + \tilde{F}(\tau, t)^{\sigma - 1 - \theta} (\tau (1 + t))^{1-\sigma}}. \tag{88}$$

To solve for an expression for N, note that substituting $\tilde{\varphi}_D$ into (84) and using (79), we

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obtain $\lambda = \frac{1}{Y}\frac{\sigma}{\theta+1-\sigma}\varphi_D^{*-\theta}f_D N$. Similarly, we can solve for $1-\lambda = \frac{(1+t)}{Y}\varphi_X^{*-\theta}f_X N\frac{\sigma}{\theta+1-\sigma}$. Now adding these expressions for $1-\lambda$ and λ and using (81) we obtain

$$N = \frac{\sigma-1}{\sigma}\left(\frac{1+\lambda t}{1+t}\right)\frac{Y}{f^E}. \tag{89}$$

Finally we note that using (82) together with (89) we can solve for the equilibrium mass of firms N and gross output Y as a function of parameters and trade costs. In particular,

$$N = \frac{\sigma-1}{\sigma}\frac{1}{f^E}\frac{\alpha w L\left(\frac{1+\lambda t}{1+t}\right)}{\left(1-\tilde{\gamma}\frac{1+\lambda t}{1+t}-\alpha\frac{t(1-\lambda)}{1+t}\right)}. \tag{90}$$

We can clearly see that in autarky we reach the limit $\lambda = 1$ and entry is given by $N^{AUT} = N|^{\lambda=1} = \frac{\sigma-1}{\sigma}\frac{1}{f^E}\frac{\alpha w L}{1-\tilde{\gamma}}$. It is also striking that firm entry takes this very same value as well as in a model with no tariffs, when we reach the limit $t = 0$, since then we have $N^{FT} = N|^{t=0} = \frac{\sigma-1}{\sigma}\frac{1}{f^E}\frac{\alpha w L}{1-\tilde{\gamma}}$. This last formula is independent of τ and this immediately implies that in a model with no tariffs, entry is not affected by changes in iceberg costs. In general we have that the change in the mass of entrants as we vary t and move form autarky to an open economy with tariffs is given by

$$\hat{N} = \frac{(1-\tilde{\gamma})\left(\frac{1+\lambda t}{1+t}\right)}{\left(1-\tilde{\gamma}\frac{1+\lambda t}{1+t}-\alpha\frac{t(1-\lambda)}{1+t}\right)}, \tag{91}$$

and this expression collapses to $\hat{N} = 1$ when $t = 0$.

B.1 Change in welfare for a change in icebergs versus tariffs

In the two-sector symmetric model, start from equation (88),

$$\lambda = \frac{1}{1+\tilde{F}(\tau,t)^{\sigma-\theta-1}(\tau(1+t))^{1-\sigma}}$$

totally differentiating this expression, we obtain

$$d\lambda = -\frac{\tilde{F}(\tau,t)^{\sigma-\theta-1}(\tau(1+t))^{1-\sigma}\left((\sigma-\theta-1)\frac{d\tilde{F}(\tau,t)}{\tilde{F}(\tau,t)}+(1-\sigma)\left(\frac{d\tau}{\tau}+\frac{dt}{(1+t)}\right)\right)}{\left(1+\tilde{F}(\tau,t)^{\sigma-\theta-1}(\tau(1+t))^{1-\sigma}\right)^2}$$

$$\frac{d\lambda}{\lambda} = -(1-\lambda)\left((\sigma-\theta-1)\frac{d\tilde{F}(\tau,t)}{\tilde{F}(\tau,t)}+(1-\sigma)\left(\frac{d\tau}{\tau}+\frac{dt}{(1+t)}\right)\right).$$

Note that

$$\tilde{F}(\tau,t)^{\sigma-\theta-1}(\tau(1+t))^{1-\sigma} = \frac{1-\lambda}{\lambda}$$

$$\tilde{F}(\tau, t) = \left(\frac{f_X}{f_D}\right)^{\frac{1}{\sigma-1}} \tau (1+t)^{\frac{\sigma}{\sigma-1}}$$

$$\frac{d\tilde{F}(\tau, t)}{\tilde{F}(\tau, t)} = \left(\frac{d\tau}{\tau} + \frac{\sigma}{\sigma-1}\frac{dt}{(1+t)}\right).$$

Therefore,

$$\frac{d\lambda}{\lambda} = \left((1-\lambda)\theta\frac{d\tau}{\tau} - (1-\lambda)\left(1-\theta\frac{\sigma}{\sigma-1}\right)\frac{dt}{1+t}\right)$$

or

$$\underbrace{\frac{d\lambda}{\lambda}}_{\text{change in domestic share}} = \underbrace{(1-\lambda)\theta\frac{d\tau}{\tau}}_{\text{from change in icebergs}} + \underbrace{(1-\lambda)(\tilde{\theta}-1)\frac{dt}{1+t}}_{\text{from change in tariffs}}$$

where $\tilde{\theta} = \theta\left(\frac{\sigma}{\sigma-1}\right)$.

Finally, using the expression for the change in welfare, we can obtain

$$\frac{dU}{U} = -\frac{\alpha}{1-\gamma}\frac{d\lambda}{\theta\lambda} + (\phi_1 - \phi_2)\frac{dN}{N},$$

where

$$\phi_1 = \left(\frac{\alpha}{1-\gamma}\right)\frac{1}{\theta}\left[\frac{\sigma-1-\Delta\theta}{(\sigma-1)(1-\Delta)}\right],$$

$$\phi_2 = \frac{\alpha}{1-\alpha}\left(\frac{1-\gamma\left(\frac{\sigma-1}{\sigma}\right)}{1-\gamma\frac{\sigma-1}{\sigma}\frac{1+\lambda t}{1+t}}\right)\frac{1+\lambda t}{1+t},$$

$$\text{and} \quad \Delta = \left[\frac{\alpha-\tilde{\gamma}}{1+\frac{t(1-\lambda)(1-\alpha)}{1+\lambda t}-\tilde{\gamma}}\right].$$

Now we use the last expression and the following expression

$$\frac{dN}{N} = (\Delta-1)\left(\frac{(1-\lambda)t}{1+\lambda t}\frac{1}{1+t}\frac{dt}{t} - \frac{t\lambda}{1+\lambda t}\frac{d\lambda}{\lambda}\right)$$

to derive

$$\frac{dU}{U} = \left(-\frac{\alpha}{1-\gamma}\frac{1}{\theta} - (\phi_1-\phi_2)(\Delta-1)\frac{t\lambda}{1+\lambda t}\right)\frac{d\lambda}{\lambda}$$
$$+ (\phi_1-\phi_2)(\Delta-1)\frac{(1-\lambda)t}{1+\lambda t}\frac{1}{1+t}\frac{dt}{t},$$

and finally

$$\frac{dU}{U} = \left(-\frac{\alpha}{1-\gamma}\frac{1}{\theta} - (\phi_1-\phi_2)(\Delta-1)\frac{t\lambda}{1+\lambda t}\right)(1-\lambda)\theta\frac{d\tau}{\tau}$$
$$+ \left(\frac{\alpha}{1-\gamma}\frac{1-\tilde{\theta}}{\theta} + (\phi_1-\phi_2)(\Delta-1)\left(1-\tilde{\theta}\frac{t\lambda}{1+\lambda t}\right)\right)\frac{(1-\lambda)}{1+t}dt. \qquad (92)$$

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B.2 Proof of Theorem 2

Theorem 2 *Consider an economy near a free trade (FT) equilibrium, $t = 0$ and $\tau > 1$. Restrict attention to the case $\gamma = 0$ (no intermediates). Then for small increases in trade frictions dt and $d\tau$ the formula for welfare changes becomes*

$$\frac{dU^{FT}}{U} \bigg/ \frac{dt}{1+t} = -\frac{\alpha(1-\alpha)}{(\sigma-1)} (1-\lambda_{ii}) \qquad \text{and} \qquad \frac{dU^{FT}}{U} \bigg/ \frac{d\tau}{\tau} = -\alpha (1-\lambda_{ii}) .$$

Equivalently, in terms of implied changes in the trade share $d\lambda_{ii}/\lambda_i$, we can write:

$$\frac{dU_i/U_i}{d\lambda_{ii}/\lambda_{ii}} \bigg|^{FT}_{d\tau=0} = -\frac{\alpha(1-\alpha)}{\theta\sigma - \sigma + 1} \qquad \text{and} \qquad \frac{dU/U}{d\lambda_{ii}/\lambda_{ii}} \bigg|^{FT}_{dt=0} = -\frac{\alpha}{\theta}. \tag{93}$$

Thus, in the case $\alpha = 1$ (one sector model) welfare losses are of the second order for tariffs since the terms on the left of the above expressions equal 0, and of the first-order for icebergs. In all other cases with $\alpha < 1$, both welfare losses are in general of the first order.

Proof. Consider an economy near a free trade equilibrium ($\tau \geq 1, t = 0$). We focus on the case in where $\gamma = 0$, no intermediate goods. Note that in this case we have that

$$\phi_1 = \frac{\alpha}{(1-\Delta)(1-\gamma)} \frac{1}{\theta} \left(1 - \frac{\Delta\theta}{\sigma - 1}\right), \qquad \phi_2 = \frac{\alpha}{1-\alpha}, \qquad \text{and} \qquad \Delta = \left(\frac{\alpha - \tilde{\gamma}}{1 - \tilde{\gamma}}\right).$$

After substituting these into (92), we get that the change in welfare near a free trade (FT) equilibrium is given by

$$\frac{dU^{FT}}{U} = -\alpha \left(\frac{1-\lambda}{1-\gamma}\right) \frac{d\tau}{\tau} - \frac{\alpha}{(1-\gamma)} \left(\frac{1-\Delta}{\sigma - 1} + \frac{\gamma - \tilde{\gamma}}{1 - \tilde{\gamma}}\right) (1-\lambda) \frac{dt}{(1+t)}.$$

Therefore, near a free trade equilibrium we have that

$$\frac{dU^{FT}}{U} \bigg/ \frac{dt}{1+t} = -\alpha \left(\frac{1-\lambda}{1-\gamma}\right) \left(\frac{1-\Delta}{\sigma - 1} + \frac{\gamma - \tilde{\gamma}}{1 - \tilde{\gamma}}\right) \qquad \text{and} \qquad \frac{dU^{FT}}{U} \bigg/ \frac{d\tau}{\tau} = -\alpha \left(\frac{1-\lambda}{1-\gamma}\right).$$

Thus, near a free trade equilibrium, we can see that both welfare changes are first order for a small change in icebergs or tariffs, provided that $\alpha < 1$ so $\Delta < 1$, or that $\gamma > 0$ so that $\tilde{\gamma} = \gamma \left(\frac{\sigma-1}{\sigma}\right) < \gamma$.

Equivalently, using $\frac{d\lambda}{\lambda} = \left((1-\lambda)\theta\frac{d\tau}{\tau} - (1-\lambda)\left(1 - \theta\frac{\sigma}{\sigma-1}\right)\frac{dt}{1+t}\right)$, we can restate this result as:

$$\text{Fixing } \tau \geq 1, \text{ varying } t: \qquad \frac{dU/U}{d\lambda/\lambda}^{FT} = -\frac{\alpha}{(\tilde{\theta} - 1)(1-\gamma)} \left(\frac{1-\Delta}{\sigma - 1} + \frac{\gamma - \tilde{\gamma}}{1 - \tilde{\gamma}}\right), \tag{94}$$

$$\text{Fixing } t = 0, \text{ varying } \tau: \qquad \frac{dU/U}{d\lambda/\lambda}^{FT} = -\frac{\alpha}{\theta(1-\gamma)}, \tag{95}$$

where we remind the reader that $\tilde{\theta} = \theta \left(\frac{\sigma}{\sigma-1}\right)$ while $\tilde{\gamma} = \gamma \left(\frac{\sigma-1}{\sigma}\right)$. In the case $\alpha = 0$ and $\gamma = 0$, the expressions reduce to the formulae shown in the theorem (with $\Delta = \alpha$). ∎

B.3 Proof of Theorem 3

Theorem 3 *(a) In regions where entry is rising ($dN_i > 0$) due to a reduction in the tariff, a necessary and sufficient condition to have $dU_i/U_i > -\frac{\alpha}{(1-\gamma)\theta}d\lambda_{ii}/\lambda_{ii}$ regardless of the values of $t \geq 0$ and $0 \leq \lambda_{ii} \leq 1$ is that*

$$\tilde{\gamma} \equiv \gamma\left(\frac{\sigma-1}{\sigma}\right) > 1 - \left(\frac{2-\alpha}{\sigma+1-[(\sigma-1)/\theta]}\right). \tag{96}$$

When entry falls, the same condition implies that $dU_i/U_i < -\frac{\alpha}{(1-\gamma)\theta}d\lambda_{ii}/\lambda_{ii}$.

(b) If $\gamma = 0$ (no intermediate goods) then $\frac{dU_i}{U_i} \lessgtr -\frac{1}{\theta}\frac{\alpha}{1-\gamma}\frac{d\lambda_{ii}}{\lambda_{ii}}$ if and only if $\frac{dN_i}{N_i} \gtrless 0$

Proof. Part (b) follows as an immediate corollary, so it remains to prove (a).

We start by obtaining a closed-form expression for welfare in the symmetric two-sector, two-county model. Welfare for a change in tariffs in the model is given by the change in real income

$$\frac{dU_i}{U_i} = -\alpha\frac{d\tilde{P}_i}{\tilde{P}_i} + \frac{dT_i}{w_iL_i + T_i}.$$

We know $T_i = \frac{t(1-\lambda_{ii})}{1+t}Y_i$, and hence

$$\frac{dT_i}{Y_i} = -\frac{td\lambda_{ii}}{1+t} + \left(\frac{1-\lambda_{ii}}{1+t}\right)\frac{dt}{1+t} + \frac{t(1-\lambda_{ii})}{1+t}\frac{dY_i}{Y_i}.$$

We can than use the fact that $\frac{Y_i}{w_iL_i+T_i} = \frac{\alpha}{1-\frac{\sigma-1}{\sigma}\gamma\left(\frac{1+\lambda_{ii}t}{1+t}\right)}$, whereby

$$\frac{dU_i}{U_i} = -\alpha\frac{d\tilde{P}_i}{\tilde{P}_i} + \frac{\alpha}{1-\frac{\sigma-1}{\sigma}\gamma\left(\frac{1+\lambda_{ii}t}{1+t}\right)}\left(\frac{1-\lambda_{ii}}{1+t}\frac{dt}{1+t} - \frac{t}{1+t}d\lambda_{ii} + \frac{t(1-\lambda_{ii})}{1+t}\frac{dY_i}{Y_i}\right).$$

Now, to develop this change in welfare expression, from the main text we have

$$\frac{dN_i}{N_i} = (\Delta-1)\left(\frac{1-\lambda_{ii}}{1+\lambda_{ii}\tau}\frac{dt}{1+t} - \frac{t}{1+\lambda_{ii}t}d\lambda_{ii}\right),$$

from (37), and also

$$\frac{dY_i}{Y_i} = \Delta\left(\frac{1-\lambda_{ii}}{1+\lambda_{ii}\tau}\frac{dt}{1+t} - \frac{t}{1+\lambda_{ii}t}d\lambda_{ii}\right),$$

from (38), so that

$$\frac{1}{\Delta}\frac{dY_i}{Y_i} = \frac{1}{\Delta-1}\frac{dN_i}{N_i},$$

and thus the change in welfare expression can be written

$$\frac{dU_i}{U_i} = -\alpha\frac{d\tilde{P}_i}{\tilde{P}_i} - \frac{\alpha}{1-\alpha}\left(\frac{1-\gamma\left(\frac{\sigma-1}{\sigma}\right)}{1-\gamma\frac{\sigma-1}{\sigma}\left(\frac{1+\lambda_{ii}t}{1+t}\right)}\right)\frac{1+\lambda_{ii}t}{1+t}\frac{dN_i}{N_i}.$$

Then using

$$\frac{d\tilde{P}_i}{\tilde{P}_i} = \frac{1}{1-\gamma}\frac{d\lambda_{ii}}{\theta\lambda_{ii}} - \frac{1}{1-\gamma}\left(\frac{1}{\theta} + \left(\frac{1}{\sigma-1} - \frac{1}{\theta}\right)\frac{\Delta}{\Delta-1}\right)\frac{dN_i}{N_i},$$

from (22), it follows that,

$$\frac{dU_i}{U_i} = -\frac{\alpha}{1-\gamma}\frac{d\lambda_{ii}}{\theta\lambda_{ii}} + \left(\frac{\alpha}{1-\gamma}\right)\frac{1}{\theta}\left[\frac{\sigma-1-\Delta\theta}{(\sigma-1)(1-\Delta)}\right]\frac{dN_i}{N_i}$$
$$-\frac{\alpha}{1-\alpha}\left(\frac{1-\gamma\left(\frac{\sigma-1}{\sigma}\right)}{1-\gamma\frac{\sigma-1}{\sigma}\frac{1+\lambda_{ii}t}{1+t}}\right)\frac{1+\lambda_{ii}t}{1+t}\frac{dN_i}{N_i}.$$

In the case where we have $dN_i > 0$ by assumption, we will have $\frac{dU_i}{U_i} > -\frac{\alpha}{1-\gamma}\frac{d\lambda_{ii}}{\theta\lambda_{ii}}$ if and only if,

$$\left(\frac{\alpha}{1-\gamma}\right)\frac{1}{\theta}\left[\frac{\sigma-1-\Delta\theta}{\sigma-1-\Delta(\sigma-1)}\right] > \frac{\alpha}{1-\alpha}\left(\frac{1-\gamma\left(\frac{\sigma-1}{\sigma}\right)}{1-\gamma\frac{\sigma-1}{\sigma}\frac{1+\lambda_{ii}t}{1+t}}\right)\frac{1+\lambda_{ii}t}{1+t}. \qquad (97)$$

Now recall that

$$\Delta \equiv \left[\frac{\alpha-\tilde{\gamma}}{1+\frac{t(1-\lambda_{ii})(1-\alpha)}{1+\lambda_{ii}t} - \tilde{\gamma}}\right] \implies \Delta \leq \left(\frac{\alpha-\tilde{\gamma}}{1-\tilde{\gamma}}\right).$$

In order for (97) to hold for all values of $t \geq 0$ and $0 \leq \lambda_{ii} \leq 1$, we replace the right-hand side by its maximum value of $\alpha/(1-\alpha)$, and we replace its left-hand side by its minimum value when $\Delta = \left(\frac{\alpha-\tilde{\gamma}}{1-\tilde{\gamma}}\right)$, both obtained when $t = 0$ or $\lambda_{ii} = 1$, so the condition becomes

$$\left(\frac{\alpha}{1-\gamma}\right)\frac{1}{\theta}\left[\frac{\sigma-1-\left(\frac{\alpha-\tilde{\gamma}}{1-\tilde{\gamma}}\right)\theta}{(\sigma-1)\left(\frac{1-\alpha}{1-\tilde{\gamma}}\right)}\right] > \frac{\alpha}{1-\alpha}. \qquad (98)$$

Cross-multiplying terms and simplifying, we can rewrite (98) as

$$\left(\frac{1-\alpha}{1-\tilde{\gamma}}\right)[(1-\alpha) - (1-\gamma)(\sigma-1)] > (1-\alpha)\frac{(\theta-\sigma+1)}{\theta}.$$

Dividing by $\left(\frac{1-\alpha}{1-\tilde{\gamma}}\right) > 0$, the condition becomes

$$(1-\alpha)\left[1 - \left(\frac{1-\tilde{\gamma}}{1-\alpha}\right)\frac{(\theta-\sigma+1)}{\theta}\right] > (1-\gamma)(\sigma-1).$$

Simplifying this condition, we obtain (96), which is (44) in the main text. The result for the case where we have $dN_i < 0$ follows directly. ∎

C   Equilibrium conditions of the model in relative terms

The parameters of the model are $\alpha_{i,s}$, σ_s, $f_{ii,s}$, $\tau_{ij,s}$, θ_s, δ, $f^E_{i,s}$, $\gamma_{i,s}$, and $\gamma_{i,ss'}$, subject to the constraints $\sum_{s=1}^S \alpha_{i,s} = 1$ and $\sum_{s'=1}^S \gamma_{i,ss'} + \gamma_{i,s} = 1$. The equilibrium conditions to solve the model are then as follows: $M \times M \times S$ ZCP conditions (18),

$$
\varphi^*_{ij,s} = \left(\frac{\sigma_s}{\sigma_s - 1}\right) \left(\frac{\sigma_s w_i f_{ij,s}}{Y_{j,s}}\right)^{\frac{1}{\sigma_s - 1}} \frac{x_{i,s} \tau_{ij,s} \left(1 + t_{ij,s}\right)^{\frac{\sigma_s}{\sigma_s - 1}}}{\tilde{P}_{j,s}};
$$

$M \times S$ goods market equilibria (29),

$$
Y_{i,s} = \frac{\sigma_s - 1}{\sigma_s} \sum_{s'=1}^S \gamma_{i,ss'} \sum_{j=1}^M \frac{\lambda_{ij,s'}}{1 + \tau_{ij,s'}} Y_{j,s'} + \alpha_{i,s} \left(w_i L_i + T_i\right);
$$

$M \times S$ sectoral prices (22),

$$
\tilde{P}_{i,s} = \left(\sum_{j=1}^M \varphi^*_{ji,s}{}^{-\theta_s} N_{j,s} \left(\frac{\sigma_s}{\sigma_s - 1} \frac{\tau_{ji,s} x_{j,s} \left(1 + t_{ji,s}\right)}{\tilde{\varphi}_{ji,s}}\right)^{1-\sigma_s}\right)^{\frac{1}{1-\sigma_s}};
$$

$M \times M \times S$ expenditure shares (24),

$$
\lambda_{ji,s} = \varphi^*_{ji,s}{}^{-\theta_s} N_{j,s} \left(\frac{\sigma_s}{\sigma_s - 1} \frac{\tau_{ji,s} x_{j,s} \left(1 + t_{ji,s}\right)}{\tilde{P}_{i,s} \tilde{\varphi}_{ji,s}}\right)^{1-\sigma_s};
$$

$M \times S$ free entry conditions (20),

$$
\sum_{j=1}^M f_{ij,s} \varphi^*_{ij,s}{}^{-\theta_s} = \frac{\theta_s - \sigma_s + 1}{\sigma_s - 1} f^E_{i,s};
$$

$M \times S$ input bundle costs (11),

$$
x_{i,s} \equiv \left(w_i / \gamma_{i,s}\right)^{\gamma_{i,s}} \prod_{s'=1}^S \left(\tilde{P}_{i,s'} / \gamma_{i,s's}\right)^{\gamma_{i,s's}};
$$

and M trade balances (27),

$$
\sum_{s=1}^S \sum_{j=1}^M \frac{\lambda_{ji,s}}{1 + \tau_{ji,s}} Y_{i,s} = \sum_{s=1}^S \sum_{j=1}^M \frac{\lambda_{ij,s}}{1 + \tau_{ij,s}} Y_{j,s}.
$$

We now show how we can express the model in relative changes. Consider the impact of a change in iceberg costs $\tau_{ji,s}$ and/or tariffs $t_{ji,s}$. Denote equilibrium prices and allocations under policy vector (τ, t), by the vector $\mathbf{y}$ and equilibrium prices and allocations under policy vector (τ', t'), by the vector $\mathbf{y}'$. In the hat notation, we let $\hat{y} = y'/y$ denote the relative change in equilibrium prices and allocations after a change in policy, for any element y of the vector $\mathbf{y}$. Similarly, $\hat{\tau}_{ji,s} = \tau'_{ji,s}/\tau_{ji,s}$ and $\widehat{(1 + t_{ji,s})} = \left(1 + t'_{ji,s}\right) / \left(1 + t_{ji,s}\right)$.

Using input bundle costs (11) before and after a change in policy, we can easily obtain (45). We then proceed to solve for the change in sectoral prices. First we solve for prices after a change in policy using equation (22),

$$\tilde{P}'_{i,s} = \left(\sum_{j=1}^{M} \varphi^{*}_{ji,s}{}'^{-\theta_s} N'_{j,s} \left(\frac{\sigma_s}{\sigma_s - 1} \frac{\tau'_{ji,s} x'_{j,s} \left(1 + t'_{ji,s} \right)}{\tilde{\varphi}'_{ji,s}} \right)^{1-\sigma_s} \right)^{\frac{1}{1-\sigma_s}}.$$

Next we use the definition of expenditure shares before the change in policy (24), and multiply and divide each expression in the summation by (24),

$$\tilde{P}'_{i,s} = \left(\sum_{j=1}^{M} \lambda_{ji,s} \widehat{\varphi^{*}}_{ji,s}^{\sigma_s-1-\theta_s} \hat{N}_{j,s} \left(\widehat{\tau}_{ji,s} \hat{x}_{j,s} \widehat{(1 + t_{ji,s})} \right)^{1-\sigma_s} \left(\tilde{P}_{i,s} \right)^{1-\sigma_s} \right)^{\frac{1}{1-\sigma_s}}, \tag{99}$$

where we use the fact that $\widehat{\varphi^{*}}_{ji,s} = \widehat{\tilde{\varphi}}_{ji,s}$. Now solve for the ZCP conditions (18) in relative changes,

$$\widehat{\varphi^{*}}_{ji,s} = \left(\frac{\hat{w}_j}{\hat{Y}_{i,s}} \right)^{\frac{1}{\sigma_s-1}} \frac{\hat{x}_{j,s} \widehat{\tau}_{ji,s} \widehat{(1 + t_{ji,s})}}{\widehat{\tilde{P}}_{i,s}}^{\frac{\sigma_s}{\sigma_s-1}}, \tag{100}$$

and substitute it into (99) to obtain

$$\widehat{\tilde{P}}_{i,s} = \left(\sum_{j=1}^{M} \lambda_{ji,s} \left[\widehat{\tau}_{ji,s} \hat{x}_{j,s} \widehat{(1 + t_{ji,s})} \right]^{-\theta_s} \hat{N}_{j,s} \left(\frac{\hat{w}_j \widehat{(1 + t_{ji,s})}}{\hat{Y}_{i,s}} \right)^{\frac{\sigma_s-1-\theta_s}{\sigma_s-1}} \left(\widehat{\tilde{P}}_{i,s} \right)^{\theta_s-\sigma_s+1} \right)^{\frac{1}{1-\sigma_s}},$$

and after combining terms we obtain (46)

$$\widehat{\tilde{P}}_{i,s} = \left(\sum_{j=1}^{M} \lambda_{ji,s} \left[\widehat{\tau}_{ji,s} \hat{x}_{j,s} \widehat{(1 + t_{ji,s})} \right]^{-\theta_s} \hat{A}_{ji,s} \right)^{\frac{1}{-\theta_s}},$$

where we define

$$\hat{A}_{ji,s} \equiv \hat{N}_{j,s} \left(\frac{\hat{w}_j \widehat{(1 + t_{ji,s})}}{\hat{Y}_{i,s}} \right)^{\frac{\sigma_s-1-\theta_s}{\sigma_s-1}}.$$

Expenditure shares in relative changes are solved in a similar way. Start from solving for the expenditure share after a change in policy using (24)

$$\lambda'_{ji,s} = \varphi^{*}_{ji,s}{}'^{-\theta_s} N'_{j,s} \left(\frac{\sigma_s}{\sigma_s - 1} \frac{\tau'_{ji,s} x'_{j,s} \left(1 + t'_{ji,s} \right)}{\tilde{P}'_{i,s} \tilde{\varphi}'_{ji,s}} \right)^{1-\sigma_s},$$

take the ratio of this expression relative to the expenditure share before the change in

policy,

$$\frac{\lambda'_{ji,s}}{\lambda_{ji,s}} = \widehat{\varphi^*}_{ji,s}^{\sigma_s-1-\theta_s} \hat{N}_{j,s} \left(\frac{\widehat{\tau}_{ji,s} \hat{x}_{j,s} \widehat{(1+t_{ji,s})}}{\widehat{\tilde{P}}_{i,s}} \right)^{1-\sigma_s}.$$

Now use the ZCP condition in relative changes (100) and combine terms to obtain the expenditure shares in relative changes (47),

$$\hat{\lambda}_{ji,s} = \hat{N}_{j,s} \left(\frac{\hat{w}_j \widehat{(1+t_{ji,s})}}{\hat{Y}_{i,s}} \right)^{\frac{\sigma_s-1-\theta_s}{\sigma_s-1}} \left[\frac{\widehat{\tau}_{ji,s} \hat{x}_{j,s} \widehat{(1+t_{ji,s})}}{\widehat{\tilde{P}}_{i,s}} \right]^{-\theta_s},$$

$$\hat{\lambda}_{ji,s} = \left[\frac{\widehat{\tau}_{ji,s} \hat{x}_{j,s} \widehat{(1+t_{ji,s})}}{\widehat{\tilde{P}}_{i,s}} \right]^{-\theta_s} \hat{A}_{ji,s}.$$

The goods market equilibrium conditions (48) and the trade balance equilibrium conditions (49) are given by (27) and (29) at policy $(\boldsymbol{\tau}', \mathbf{t}')$.

Finally, to solve for the change in entry, note that, from the free entry condition (20) and imposing trade balance (27), we obtain

$$N_{i,s} = \frac{E_{ii,s} + E_{i,s}}{w_i f_{i,s}^E \left(\frac{\sigma_s}{\sigma_s-1} \right)},$$

and expressing this in relative terms we end up with (50).

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