EBERHARD KARLS
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University of Tübingen
Working Papers in
Economics and Finance

No. 53

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A Quantitative Perspective on the Gains from Trade

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A Quantitative Perspective on the Gains from Trade*

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March 2013

Abstract

Recent quantitative trade models treat import tariffs as pure cost shifters so that their effects are similar to iceberg trade costs. We introduce revenue-generating import tariffs, which act as demand shifters, into the framework of Arkolakis, Costinot and Rodriguez-Clare (2012), and generalize their gains from trade equation. Our formula permits easy quantification based on countries' observed degrees of openness, tariff revenues, and on the gravity elasticities of tariffs and icebergs. Export selection drives a wedge between these two elasticities and matters for welfare gains. However, in all model variants, an analysis based on iceberg costs necessarily underestimates the true gains from trade relative to autarky. Our quantitative exercise suggests that the bias can be numerically significant. For countries with relatively high tariffs, our formula predicts 30-60% larger gains from trade when iceberg trade costs and/or tariffs are liberalized as compared to a pure reduction of iceberg trade costs.

JEL-Classification: F10, F11, F12.

Keywords: Gravity Equation; Monopolistic Competition; Heterogeneous Firms; Armington Model; International Trade; Trade Policy; Gains from Trade

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*We would like to thank José de Sousa, Swati Dhingra, James Harrigan, Wilhelm Kohler, Thierry Mayer, Giordano Mion, John Morrow, Peter Neary, Dennis Novy, Emanuel Ornelas, Michael Pflüger, Veronica Rappoport, Jens Südekum, and participants at seminars at the Kiel Institute, the Paris School of Economics, the London School of Economics, the EEA meeting 2012 in Malaga, the ETSG meeting 2012 in Leuven, and the Midwest International Economics Meeting 2012 in St. Louis for comments and suggestions. An earlier draft of this paper circulated as *University of Tübingen Working Papers in Economics and Finance* No. 41 (2012).

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1 Introduction

Arkolakis, Costinot and Rodriguez-Clare (2012, henceforth ACR) provide a simple formula that allows computing the welfare gains relative to autarky based on a single statistic, the observed share of a country's trade with itself, and on a single parameter, the trade elasticity obtained from a gravity equation. That formula holds in a class of popular one-sector models.[1] While the required trade elasticity may have different structural interpretations in the different models, it is always the trade flow elasticity of iceberg trade costs.

Two main conclusions emerge from ACR's analysis: (i) The novel features stressed in the recent literature–imperfect competition and the presence of an extensive margin–have no extra role to play for the *ex-post* analysis of trade liberalization scenarios. So, the richer micro-level detail contained in new trade models "has not added much" to the gains from trade. (ii) Applying their formula to the US, ACR show that the gains from trade obtained from the class of models encompassed by their analysis are quantitatively rather small. Going from autarky to the status quo leads to welfare gains of 0.7 to 1.4% of GDP.

To obtain these results, ACR restrict the allowed exogenous variation to changes in iceberg trade costs, foreign labor endowments, or fixed market access costs. In this paper, we extend the analysis to import tariffs. We show that ACR's conclusion (i) requires qualification. Conditional on a country's observed trade share, the welfare gains from trade liberalization are the same across models only if the gravity elasticities of iceberg trade costs and of tariffs *coincide*. This is the case in the Armington (1969), Krugman (1980) and Eaton and Kortum (2002) models. In contrast, the two elasticities generally differ in the Melitz (2003) model.[2] It follows that the presence of a selection channel combined with monopolistic competition has a quantitative bearing on the gains from trade.

In all models considered, tariffs change the welfare formula and therefore also affect conclusion (ii). For the quantitative exercise, besides the iceberg trade costs elasticity, one also

[1] The frameworks covered include the Armington (1969), Krugman (1980), Eaton and Kortum (2002) and Melitz (2003) models. Costinot and Rodriguez-Clare (2013) provide an excellent overview on how the simple welfare formula extends to cover models with multiple sectors, intermediate goods, and multiple factors of production.

[2] They coincide only if one treats tariffs as cost shifters, so that they increase marginal costs for the producer.

requires the trade flow elasticity of tariffs, and, besides the trade share, one also requires the share of tariff revenue in total GDP. We find that the ACR formula necessarily underestimates the gains from trade relative to autarky: in the presence of non-zero tariffs and tariff revenue, the calculated gains from trade are always larger when accounting for revenue-generating tariffs as compared to a situation where tariffs are assumed to be absent.

The generalized welfare formula can be brought to the data as easily as ACR's original formula. Using the same calibration strategy as ACR, and even concentrating on models in which tariffs and iceberg trade costs feature the same gravity elasticity, we find that tariffs can matter very significantly: for example, in the year 2000, the specification only accounting for iceberg trade costs underpredicts the gains from trade for Australia by 34.5 to 51.2%, for Korea by 21.6 to 35.3% and for the U.S. by 8 to 14.8%, where the ranges result from different choices of trade elasticities.

ACR acknowledge that "... *our main welfare formula would need to be modified to cover the case of tariffs. In particular, the results derived ... ignore changes in tariff revenues, which may affect real income both directly and indirectly (through the entry and exit of firms).*"[3] In this paper we propose such a modified formula. The fact that iceberg trade costs and tariffs may have quite different effects on outcomes has been discussed in various papers but, to the best of our knowledge, the literature does not yet offer a comparative quantitative perspective à la ACR. Cole (2012) uses the framework of Chaney (2008) to show that the trade flow elasticity of tariffs is larger than that of iceberg trade costs. He argues that estimates derived from variables such as distance may underestimate the trade-enhancing effects of tariff reforms. We show that the different welfare effects derive more from the fact that tariffs generate revenue rather than from differences in elasticities.

Result (i) of ACR has prompted responses from the CGE literature. Balistreri, Hillberry, and Rutherford (2011) point out that "*[revenue-generating tariffs rather than iceberg trade costs] can generate differences in the Melitz formulation relative to a perfect competition model*" (p. 96). Summarizing Balistreri and Markusen (2009), they furthermore argue that "*removing rent-*

[3]See ACR (2012, footnote 33). Moreover, in their analysis of tariff reform in Costa Rica, Arkolakis, Costinot and Rodriguez-Clare (2008) model trade reform as lower iceberg trade costs. They write: "*One drawback of the model we present here is that we treat tariffs as transportation costs*".

generating tariffs have different effects in monopolistic competition versus Armington models, because optimal tariffs are different"(p. 96). These findings are based on simulations. We provide an analytical proof that the first assertion holds and show why it does so. It entirely depends on the difference between the iceberg trade costs and the tariff elasticities in the Melitz (2003) model. The second assertion, in contrast, is not generally true, since, for example, the Krugman (1980) and the Armington (1969) models do admit identical welfare expressions.

Also, result (ii) of ACR has triggered substantial further work. One debate relates to the role of *pro competitive gains* from trade. Arkolakis, Costinot, Donaldson, and Rodriguez-Clare (2012) show for a single-sector Melitz (2003) model with Pareto distributed productivities and variable markups that pro-competitive gains from trade are negative. Edmond, Midrigan and Xi (2012) use a multi-sector framework with oligopolistic competition and come to opposite conclusions. Another strand of research highlights the role of cross-industry differences in trade elasticities. Ossa (2012a) shows that a multi-sector Armington framework yields substantially larger aggregate welfare gains than a single-sector model. Moreover, ACR have already noticed the role of *multiple sectors* for their result (i). In such an environment, some sectors have higher gains under monopolistic competition than under perfect competition and other sectors have lower gains. The aggregate welfare effect depends on sectoral weights and is ambiguous. In the presence of *intermediate goods* the gains from trade are always larger under monopolistic competition than under perfect competition.[4]

Our work is related to two more areas of research. First, recent quantitative trade models have acknowledged the role of tariffs besides iceberg trade costs. For example, Alvarez and Lucas (2007) use the Eaton and Kortum (2002) model to study the effects of tariff reform. Ossa (2012b) studies optimal tariffs and tariff wars in an extension of the Krugman (1980) model. Caliendo and Parro (2012) provide a quantitative analysis of tariff liberalization in the context of NAFTA and stress the role of input-output linkages across sectors. While these models study tariffs, they do not make the role of tariffs for ACR's results (i) and (ii) explicit. This is the focus of the present study. Second, our analysis links to the structural econometric estimation

[4]ACR also show that the gravity elasticity of trade cost is not sufficient to compute welfare gains in the presence of multiple sectors or intermediate goods.

of gravity models since these deliver the elasticities that turn out so crucial. Separate estimation of the iceberg and tariff elasticities is difficult. The problem is that iceberg trade costs are not directly observed and that tariff levels are likely to be endogenous. However, Crozet and Koenig (2010) have developed a method to estimate the parameters underlying the tariff and iceberg trade cost elasticities without knowledge of trade frictions by using firm-level data.

We have structured the remainder of this paper as follows: Section 2 introduces the model setup and explains how the introduction of tariffs alters the ACR framework. Section 3 characterizes welfare in the presence of tariffs. Using observed openness and tariff revenue, Section 4 shows that the gains from trade can be severely underestimated when the variation in openness is assumed to be due only to changes in iceberg trade costs while the reality does feature tariffs. Finally, Section 5 concludes.

2 Import tariffs in quantitative trade models

2.1 Preferences, technology, trade costs, and market structure

We introduce import tariffs into quantitative trade models à la ACR. We focus on four particular models that satisfy the primitive assumptions and macro-level restrictions outlined in ACR: (i) a simple Armington model, (ii) Eaton and Kortum (2002) as an example of a Ricardian model, (iii) the Krugman (1980) monopolistic competition model and, (iv) the Melitz (2003) model with Pareto-distributed productivities and foreign market access cost in terms of foreign labor.[5]

Preferences. The representative household in country i, $i \in 1..n$, has symmetric CES preferences (Dixit-Stiglitz)

$$U_i = \left(\int_{\omega \in \Omega_i} q_i \left[\omega \right] \right)^{1/\rho}, \tag{1}$$

where Ω_i is the set of differentiated varieties available in country i, $q_i\left[\omega\right]$ is the quantity of variety ω consumed in country i and $\sigma = 1/\left(1-\rho\right) > 1$ is the constant elasticity of substitution.[6] The

[5]Expressing foreign market access costs in terms of foreign labor provides a gravity equation that obeys a particularly tractable functional form. In some applications, it is possible to nest the Krugman (1980) model within the Krugman (1980) model.

[6]We use square brackets to denote functional relationships.

price index dual to (1) is $P_i^{1-\sigma} = \int_{\omega \in \Omega_i} p_i [\omega]^{1-\sigma} d\omega$.

Technology and trade costs. Labor is the only factor of production and is supplied inelastically at quantity L_i and price w_i. Output is linear in labor, and productivity may or may not differ across firms, with b_i denoting the minimum productivity level. International trade is subject to frictions while intranational trade is frictionless. In all models considered, exporting from i to j involves iceberg trade costs τ_{ij}, where $\tau_{ii} = 1$. Moreover, in Melitz (2003) there are fixed market access costs, assumed to be in units of the destination country's labor, that have to be paid to serve the home or the foreign market.

Structure of product markets. There are two types of market structures: perfect competition and monopolistic competition with free entry. In both situations, firms take wages and aggregate variables as given. With perfect competition, fixed innovation and market access costs are zero. With monopolistic competition, in contrast, firms have to pay to obtain blueprints for production. The allocation of these potentially heterogeneous blueprints across firms is random.

Tariffs. The key difference to ACR is that each country j may impose an *ad valorem tariff* $t_{ji} \geq 1$ on its imports from country i, where $t_{ii} = 1$. We assume that tariff revenue is redistributed lump-sum to consumers. As opposed to iceberg trade costs, a tariff distorts consumption decisions towards domestic goods but does not entail loss in transit.

2.2 Macro-level restrictions and the gravity equation

In their analysis, ACR impose three restrictions whose key role is to ensure that the framework described above gives rise to a gravity equation, i.a., a representation of bilateral trade flows where elasticities are constant. The first restriction, R1, requires that trade is balanced on a multilateral level; the second, R2, mandates that aggregate gross profits are proportional to aggregate revenue, and the third, R3', puts a functional form on the gravity equation.

R2 needs no further qualification in the context of our exercise. R1, the balanced trade condition, warrants a comment. In the presence of tariffs, it does not imply that aggregate firm revenue and aggregate consumer spending are the same. To see this, let X_{ij} denote the value of country $j's$ total imports from country i in *domestic* prices (i.e., gross of tariff, gross of iceberg trade costs), then balanced trade requires

$$\sum_{i=1}^{n} \frac{X_{ji}}{t_{ij}} = \sum_{i=1}^{n} \frac{X_{ij}}{t_{ji}}, \text{ for all } j. \tag{2}$$

Aggregate revenue *accruing to firms* is given by $R_j \equiv \sum_{i=1}^{n} X_{ji}/t_{ij}$, while, with tariff income, *consumer's* aggregate expenditure is $X_j \equiv \sum_{i=1}^{n} X_{ij}$. Hence, balanced trade does not imply $X_j = R_j$, a restriction heavily employed by ACR.

R3' makes a restriction on functional forms so that trade flow equations resulting from the model are similar to known gravity model forms. We employ a similar, albeit slightly more general restriction (R3') of the form

$$\frac{X_{ij}}{X_{jj}} = \frac{\chi_{ij}}{\chi_{jj}} \frac{N_i}{N_j} \left(\frac{w_i}{w_j} \tau_{ij} \right)^{\varepsilon} t_{ji}^{\zeta}, \tag{3}$$

which accommodates the presence of tariffs. Dividing by X_{jj} eliminates income X_j and the multilateral resistance term à la Anderson and van Wincoop (2003). χ_{ij} collects constants different from iceberg trade costs τ_{ij} and tariffs t_{ji}. N_i is the mass of firms potentially active in country i. That mass is endogenously determined, but due to R1 and R2, N_i is proportional to exogenous labor endowment L_i so that N_i does not change in a comparative statics exercise on τ or t. The elasticities ε and ζ are constants with negative signs. In ACR, the term t_{ji}^{ζ} is not present.

ACR show that the Armington model by Anderson and van Wincoop (2003) satisfy R1 to R3' without further restrictions. However, the Eaton-Kortum (2002) and Melitz (2003) models satisfy R2 and R3' only under strong functional form assumptions on the distribution governing within country heterogeneity that make sure that there is a unique trade elasticity despite the presence of two margins of adjustment (intensive/extensive). The same functional form restrictions are required in the presence of tariffs (i.e., the Fréchet distribution in the Eaton and Kortum (2002) framework and the Pareto distribution in the Melitz (2003) case).

Table 1 provides the details on the structural interpretation of the tariff and iceberg trade cost elasticities from equation (3) for the different models considered in our analysis.[7] $\gamma > \sigma - 1$ is the (unique, positive) parameter of the Fréchet distribution governing unit labor requirements in Eaton and Kortum (2002), and $\theta > \sigma - 1$ is the (unique, positive) parameter of the Pareto distribution governing firm-level productivity draws in a parameterized version of Melitz (2003).

Table 1: Iceberg trade costs and tariff elasticities in various trade models

	Armington (1969), Krugman (1980)	Eaton&Kortum (2002)	Melitz (2003)
Iceberg trade cost elasticity ε	$1-\sigma$	$-\gamma$	$-\theta$
Tariff elasticity ζ	$1-\sigma$	$-\gamma$	$1-\theta/\rho$

In Armington (1969), Krugman (1980), and Eaton and Kortum (2002) we have $\varepsilon = \zeta$ since we define export flows as inclusive of tariffs.[8] In Melitz, we have $\varepsilon > \zeta$ since $\theta > \sigma - 1$. The Melitz-gravity equation collapses to the Krugman (1980) formulation if one considers the limiting case $\theta \to \sigma - 1$. This effectively deactivates firm selection. This suggests that the discrepancy between ε and ζ in the Melitz model originates from the existence of a firm-extensive margin.

The distinction between ε and ζ is important. To provide intuition, we follow Head and Mayer (2013) and decompose trade elasticities in the Melitz framework into an intensive, an extensive, and a compositional margin, such that[9]

$$\frac{d\ln X_{ij}}{d\ln \vartheta_{ij}} = \underbrace{1-\sigma}_{\text{intensive margin}} - \underbrace{\theta\frac{d\ln \varphi^*_{ij}}{d\ln \vartheta_{ij}}}_{\text{extensive margin}} + \underbrace{(\sigma-1)\frac{d\ln \varphi^*_{ij}}{d\ln \vartheta_{ij}}}_{\text{compositional margin}}, \tag{4}$$

where $\vartheta_{ij} \in \{\tau_{ij}, t_{ji}\}$ and φ^*_{ij} is the minimum productivity level required for a firm to cover the fixed costs of foreign market presence. The *intensive* margin records changed import spending on varieties already sold on the market of country i, holding the number of imported varieties and the price distribution constant; the *extensive* margin relates to the change in the mass of foreign exporters, holding sales constant; and the *compositional* margin describes the reallocation of

[7]See Appendix B for the detailed derivations.

[8]This is just a convention that somewhat eases notation in our framework. Writing trade flows net of tariffs yields a gravity coefficient on tariffs of $\varepsilon - 1$, and requires rewriting the balanced trade condition. None of our results would change.

[9]See Appendix D for full details on the derivation.

spending resulting from changes in the price distribution holding the number of firms and firm-level sales constant. Clearly, when all firms export, there are no extensive and compositional margins. Elasticities ε and ζ coincide, since iceberg trade costs and tariffs increase the consumer price of a variety in exactly the same way. For the same reason, even in the presence of additional margins, the change in optimal demand for a single variety (i.e., the intensive margin) is exactly the same regardless of whether prices change due to variation in τ_{ij} or t_{ji}.

In contrast, tariffs and iceberg trade costs have different implications for firms' revenues. For given consumer demand, a producer has to increase output in response to a rise in iceberg trade costs as τ_{ij} units have to be produced for one unit to arrive. Compared to a change in the tariff t_{ji}, which has no such effect on firm revenue, firm sales are higher compared to the same change in τ_{ij}; with constant markups this leads to larger gross operating profits, motivating the entry of less productive firms.[10] In terms of the algebra of the Melitz (2003) model, these considerations imply $d\ln\varphi^*_{ij}/d\ln\tau_{ij} = 1$ while $d\ln\varphi^*_{ij}/d\ln t_{ji} = \sigma/(\sigma-1)$. In absolute terms, the effect of an increase in iceberg trade costs on the mass of foreign exporters is smaller than the effect of an import tariff. Substituting into (4), it follows that $\varepsilon > \zeta$.[11]

2.3 Identities

Expenditure and income. The government's *tariff revenue* is given by

$$T_j \equiv \sum_{i=1}^{n} \frac{t_{ji}-1}{t_{ji}} X_{ij}, \tag{5}$$

where X_{ij}/t_{ji} is the value of imports from i exclusive of tariffs. The representative household receives a share $\eta_j \in [0,1]$ of tariff revenue, the complementary share being wasted in the

[10]This most easily seen by comparing import zero cutoff profit conditions for the case of a tariff (see A.3.4 in Demidova and Rodriguez-Clare, 2009) with the more standard iceberg case.

[11]In the Appendix, we show that this result does not depend on whether fixed foreign market entry costs are in terms of domestic or foreign labor. Neither does it depend on whether or not tariff revenue is successfully rebated to consumers. One obtains $\varepsilon = \zeta$ even under firm selection if tariffs are treated as cost shifters rather than demand shifters. This would amount to the situation where the exporter treats tariffs as marginal costs and applies the markup to this enlarged cost base. Then, tariffs act exactly like iceberg trade costs. However, this configuration is unrealistic; it is also not in line with the usual interpretation: tariffs drive a wedge between producer and consumer prices. This is what leads to $\varepsilon > \zeta$.

redistribution process.[12] With $\eta < 1$, import tariffs directly consume resources as do iceberg trade costs. An important difference, however, is that iceberg trade costs waste resources of the *exporting* country, whereas import tariffs waste resources of the *importing* country.

Aggregate expenditure X_j (equal to aggregate income) is made up of labor income $w_j L_j$ and effective tariff revenue $\eta_j T_j$

$$X_j = w_j L_j + \eta_j T_j = \mu_j w_j L_j, \tag{6}$$

where μ_j is a tariff multiplier defined as

$$\mu_j \equiv \left(1 + \frac{\eta_j T_j}{w_j L_j}\right) = \left(1 - \frac{\eta_j T_j}{X_j}\right)^{-1} \geq 1. \tag{7}$$

The multiplier μ_j arises because spending labor income on imports generates tariff income which is part of aggregate income.[13] The tariff multiplier is inactive if a country does not impose import tariffs ($T_j = 0$) or if tariff revenue is completely wasted ($\eta_j = 0$). Equation (6) greatly simplifies our analysis for two reasons. First, there is no need to keep track of bilateral trade flows and bilateral tariffs. All relevant information is represented by the share of aggregate tariff revenue in aggregate income, which is easily observable. Second, it allows expressing aggregate labor income as a function of total income and the share of tariff revenue in aggregate income (GDP). Since labor is the only factor of production, and profits are fully competed away by free entry, firm revenues are paid out to workers as *labor income* $w_j L_j$. Hence,

$$w_j L_j = R_j = \sum_i^n \frac{X_{ji}}{t_{ij}}, \tag{8}$$

where dividing by t_{ij} takes care of X_{ji} being defined as inclusive of tariffs.

[12] Neary (1994) studies distortionary taxation of firms under oligopolistic competition in an international export subsidy game. Alternatively, one can read η_j as the share of tariff revenue which is not wasted on rent-seeking activities; see Schröder and Sørensen (2011).

[13] Although we limit our analysis to import tariffs $t_{ji} > 1$, our model can easily be extended to import subsidies $t_{ji} < 1$. A tariff multiplier μ_j larger than unity obtains if *net* tariff revenue is positive.

Expenditure share. ACR express country j´s welfare as a function of the share of *expenditure* that falls on its own (domestically produced) goods, i.e.,

$$\lambda_{jj} \equiv \frac{X_{jj}}{X_j} = \left(1 + \sum_{i \neq j} X_{ij}/X_{jj}\right)^{-1}. \tag{9}$$

That share is an inverse measure of $j's$ openness also referred to as its degree of "autarkiness"; $1 - \lambda_{jj}$ would then be its openness.[14]

3 Welfare analysis

3.1 A generalized formula for the gains from trade

We are interested in the effects of import tariffs on welfare. Welfare is given by the per capita value of real income accruing to consumers

$$W_j = \frac{X_j}{L_j P_j} = \mu_j \frac{w_j}{P_j}, \tag{10}$$

where the second equality makes use of (6). Importantly, welfare not only depends on real labor income, but also on redistributed real tariff revenue.

As outlined above, the tariff multiplier μ_j is computed from aggregate tariff revenue as a share of aggregate income. Real labor income is essentially unobserved. In Appendix C, however, we show that the change in real labor income can be expressed in a multiplicative fashion as a function of the change in the tariff multiplier and the change in the share of domestic expenditure share as

$$\widehat{\left(\frac{w_j}{P_j}\right)} = \widehat{\mu}_j^{\frac{\zeta}{\varepsilon}-1} \widehat{\lambda}_{jj}^{1/\varepsilon}, \tag{11}$$

where as in ACR $\widehat{x} \equiv x'/x$ denotes the change in any variable x between the initial and the new equilibrium.[15] Three observations stand out. First, with $\varepsilon = \zeta$ the change in real income can

[14] In the following, with some abuse of wording, we similarly refer to changes in autarkiness or openness when describing changes in λ_{ii}.

[15] The intuition behind the result is the same as in ACR. Our proof, however, is simpler as we do not make use of "hat" algebra. The reason is that we focus on three particular examples of quantitative trade models and not on the whole class of models.

be computed from the change in the share of domestic expenditure as in ACR. Second, with $\varepsilon \neq \zeta$ computation of the change in real labor income becomes more complex since, additionally, information on the change in the tariff multiplier is necessary. The reason is that tariff income affects the mass of foreign firms exporting to country j, a margin which has repercussions on the price index and which is not active in the other models.[16] Finally, the change in real labor income does not represent the change in utility of country j's representative consumer as tariff income has to be taken into account. Combining equations (10) and (11) leads to the following proposition.

Proposition 1 *In the considered trade models (Armington (1969), Krugman (1980), Eaton and Kortum (2002), and Melitz (2003)), the change in real income associated with a change in tariffs and/or iceberg trade costs can be computed as*

$$\widehat{W}_j = \widehat{\mu}_j^{\frac{\zeta}{\varepsilon}} \widehat{\lambda}_{jj}^{\frac{1}{\varepsilon}}.$$

Conditional on observed $\widehat{\lambda}_{jj}, \widehat{\mu}_j$ and given trade elasticities ε, ζ, $\widehat{W}_j$ is larger in the Melitz (2003) model (where $\zeta/\varepsilon > 1$) than in the other models (where $\zeta/\varepsilon = 1$).

Proof. *Immediately follows from combing equations (10) and (11).* ■

Proposition 1 states that for the set of quantitative trade models considered, the change in welfare can be computed from the change in the tariff multiplier and the change in the domestic expenditure share, given the elasticities ε and ζ. The formula collapses to the one presented by ACR in the absence of tariffs, i.e., $\widehat{W}_j^{ACR} = \widehat{\lambda}_{jj}^{1/\varepsilon}$. As in ARC, Proposition 1 can be used to infer welfare consequences of past episodes of trade liberalization. In particular, one can very easily compute the gains from trade relative to autarky, for which $\lambda_{jj} = 1$ and $\mu_j = 1$.

As long as one imposes the restriction on gravity parameters $\varepsilon = \zeta$, the exact micro foundation of the models does not matter for the size of welfare gains, even in the presence of tariffs. However, this isomorphism breaks in the Melitz (2003) model where $\varepsilon > \zeta$. Hence, the combination of tariff revenue, firm selection and monopolistic competition matters for the gains from

[16] Although the Eaton and Kortum (2002) model features selection, the mass of firms active in international trade has no particular role due to perfect competition. In the special case in which Melitz (2003) replicates the Krugman (1980) model, i.e., $\theta \to \sigma - 1$, it also yields $\zeta \to \varepsilon$.

trade.[17]

Proposition 1 also characterizes welfare effects of variable trade costs that consume resources of the *importing* country rather than resources of the *exporting* country. With $\eta_j = 0$, tariff revenue is completely wasted, and the tariff multiplier μ_j is fixed at unity. Then, the welfare formula collapses to the one presented by ACR. So, in the considered quantitative trade models, the welfare effect of a shock on variable trade cost that consume resources either of the exporting or the importing country is simply $\widehat{W}_j = \widehat{\lambda}_{jj}^{\frac{1}{\varepsilon}}$. This observation implies that the formula presented in ACR characterizing the effect of iceberg type trade costs also applies to the liberalizing (exporting) country.[18]

3.2 Ignoring tariffs leads to underestimation of the true gains from trade

In general, the ACR welfare formula may over- or underestimate the true gains from trade. Conditional on the observed change in the domestic expenditure share, the ACR formula overestimates the welfare gains if $\widehat{\mu}_j < 1$. This overestimation occurs if the share of tariff income in aggregate income has fallen during liberalization. If, on the other hand, this share has risen, the ARC formula underestimates the gains from trade reform. In particular, we show that the ACR formula underestimates the gains from trade in the case of moving from autarky to the observed equilibrium. By definition, trade costs (either iceberg trade costs or tariffs) are prohibitive under autarky, such that the economy raises no tariff revenue in the initial equilibrium.

How sensitive is the underestimation of the welfare gains from trade for a given domestic expenditure share and given tariff multiplier to the changes in the elasticities ε and ζ and their determinants σ, γ, and θ? We answer this question in the following proposition.[19]

Proposition 2 *Ignoring tariff revenue, the ACR formula underestimates the true gains from*

[17] With $\varepsilon = \zeta$, firm selection stops operating in the Melitz (2003) model.

[18] ACR focus on welfare effects in the *importing* country.

[19] For the purpose of understanding the nature of the underestimation problem, we treat both λ_{jj} and μ_j as exogenous, while they are, of course, endogenous variables in the model. We do not report general equilibrium comparative statics results.

trade relative to autarky by

$$\kappa_j(\%) \equiv 100 \left| \frac{\lambda_{jj}^{\frac{1}{\varepsilon}} - 1}{\mu_j^{\frac{\zeta}{\varepsilon}} \lambda_{jj}^{\frac{1}{\varepsilon}} - 1} - 1 \right|.$$

(a) κ_j *is increasing in the share of domestic expenditure* λ_{jj} *and in the tariff multiplier* μ_j*.*

(b) If iceberg trade cost and tariff elasticities coincide as in Armington (1969), Eaton and Kortum (2002), and Krugman (1980), κ_j *is decreasing in the trade elasticity.*

(c) If iceberg trade cost and tariff elasticities are given by respectively $\varepsilon = -\theta$ *and* $\zeta = 1 - \theta/\rho$ *as in Melitz (2003),* κ_j *is decreasing in the degree of productivity dispersion* $1/\theta$ *and in the elasticity of substitution* σ*.*

Proof. See Appendix E. ■

Proposition 2 implies that in the Armington case and in Krugman as a special case of the Melitz model, underestimation becomes more severe the larger the elasticity of substitution. In the Eaton-Kortum case, underestimation falls in the degree of heterogeneity across goods in countries' labor efficiency levels.[20] In the Melitz framework, κ_j falls in the elasticity of substitution, which contrasts the findings for the Armington and the Krugman model.[21] The effect of productivity dispersion is *a priori* unclear, as the domestic expenditure share is smaller than one, whereas the tariff multiplier is larger than one. We show in Appendix E that κ_j is unambiguously increasing in θ. Hence, for given λ_{jj} and μ_j, higher productivity dispersion (lower θ) leads to less severe underestimation.

3.3 Effects of symmetric liberalization

In order to build intuition for what happens if trade is liberalized along both margins, iceberg trade costs and tariffs, we characterize the tariff multiplier and analyze the gains from trade in a situation. For $\eta = 1$, we consider the welfare effects of reducing (i) iceberg trade costs for given tariffs, and (ii) tariffs for given iceberg trade costs. It turns out that allowing for variation in iceberg trade costs but fixing tariffs retains the convex relationship between welfare and the

[20] Recall that γ is inversely related to heterogeneity.

[21] Note that σ and ρ are positively correlated.

share of domestic expenditure known from ACR. Quite to the contrary, dismantling tariffs yields a concave relationship. In the data, of course, we see a combination of both.

To derive our theoretical argument, we employ a framework with two symmetric countries. In this setting, we can abstract from terms-of-trade considerations. Moreover, we can express the tariff and therefore the tariff multiplier as a function of the domestic expenditure share, which allows for a simple graphical representation of the gains from trade.

The tariff multiplier. With two symmetric countries, the tariff multiplier can be written as

$$\mu = \frac{t}{\lambda\,(t-1)+1}, \tag{12}$$

which follows from the definition of tariff revenue T given by equation (5). Totally differentiating this expression, we obtain

$$d\ln\mu = \frac{1-\lambda}{\lambda\,(t-1)+1} d\ln t - \frac{\lambda\,(t-1)}{\lambda\,(t-1)+1} d\ln\lambda, \tag{13}$$

where the first term on the right hand side of the equation represents a *tariff rate effect.* For a given domestic expenditure share, the tariff multiplier is increasing in the tariff. The third term is a *tax base effect.* For a given tariff, the tariff multiplier is decreasing in the domestic expenditure share. Evaluated at the free trade equilibrium, $t = 1$, the tax base effect is inactive, but the tariff rate effect amounts to $(1-\lambda)\,d\ln t$. Under autarky, $\lambda = 1$, the tariff rate effect is inactive, but the tax base effect is given by $(1-1/t)\,d\ln\lambda$.

Exploiting the functional form restriction on gravity (3), for fixed non-tariff barriers the change in the domestic expenditure share and the change in the tariff are linked by

$$d\ln\lambda = -\,(1-\lambda)\,\zeta d\ln t. \tag{14}$$

Substituting this expression back into equation (13), the tariff t^* that maximizes the tariff multiplier, i.e., tariff revenue relative to aggregate income, is implicitly given by

$$t^* = 1 - \frac{1}{\zeta\lambda} > 1,$$

where the inequality follows from recalling that ζ is a negative elasticity.[22] The μ-schedule follows the logic of a Laffer curve. Tariff revenues rise in the tariff rate for small tariff rates up to its maximum and then fall to zero as the tariff rate grows larger and larger. The extent to which the ACR formula underestimates the welfare gains from trade relative to autarky is therefore larger for intermediate values of the domestic expenditure share.

Given the absence of terms-of-trade considerations, the welfare-maximizing tariff is given by $t^o = 1$. Therefore, the tariff that maximizes the tariff multiplier is larger than the tariff that maximizes welfare.

Iceberg trade costs in the presence of tariffs. Consider now a change in iceberg trade costs in the presence of a constant tariff $\bar{t}$. The change in welfare is

$$\left.\frac{d\ln W}{d\ln\lambda}\right|_{t=\bar{t}} = \frac{1}{\varepsilon}\left(1-\zeta\frac{\lambda\,(t-1)}{\lambda\,(t-1)+1}\right). \tag{15}$$

Recall that ε and ζ are negative elasticities. Welfare is therefore strictly decreasing in λ. The first term in brackets on the right hand side represents an import price effect, and the second term is a tax base effect. Clearly there is no tax base effect in the absence of tariffs, $t = 1$. In this case, the formula collapses to the ACR result, and welfare is strictly convex in λ. Using equation (15), we show in Appendix F that welfare is still convex in λ in the presence of tariffs.

Lowering tariffs. Consider a change in tariffs for given iceberg trade costs $\bar{\tau}$. Using equation (14) to substitute out $d\ln t$ from equation (13), we can write the change in welfare as

$$\left.\frac{d\ln W}{d\ln\lambda}\right|_{\tau=\bar{\tau}} = \frac{1}{\varepsilon}\left(1-\zeta\frac{\lambda\,(t-1)}{\lambda\,(t-1)+1}-\frac{1}{\lambda\,(t-1)+1}\right), \tag{16}$$

where as in equation (15) the first term is the import price effect, and the second term is a tax base effect. These terms are accompanied by the tariff rate effect. Evaluated at free trade equilibrium, $t = 1$, the second term in brackets disappears, and the third term simplifies to unity. Hence, the import price effect is exactly offset by the tax rate effect, and a small tariff

[22] The tariff-multiplier maximizing tariff t^* follows from setting $d\ln\mu/d\ln\lambda$ to zero.

therefore has no net welfare consequences. Evaluated at the autarky equilibrium, $t \to \infty$, the tariff rate effect is absent, and the tax base effect converges to $-\zeta$. Clearly, there would be no tax base effect if autarky was generated through prohibitive non-tariff barriers.

Using equation (16), we show in Appendix F that welfare is concave in the domestic expenditure share when variation in the expenditure share is solely driven by changes in import tariffs.

Proposition 3 *In a symmetric two-country world with tariffs t and iceberg trade costs τ*

(a) variation in τ for given t yields a convex downward sloping relationship between welfare and autarkiness λ, while

(b) variation in t for given τ generates a concave, downward sloping relationship.

Proof. See Appendix F.[23] ■

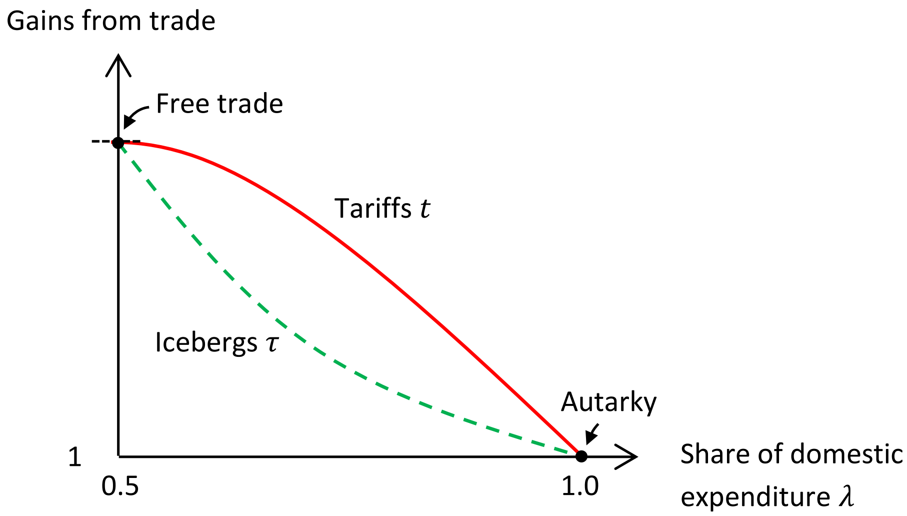
Figure 1 provides an illustration of the two polar cases, with autarky welfare normalized to unity. Clearly, since welfare is the same for the two cases in either autarky (when either τ or t or both are prohibitively high) or free trade (when trade is entirely free), for values of $\lambda \in [0.5, 1]$, the concave curve has to lie above the convex one, so that a lens opens up. The height of the lens describes the potential maximum amount of underestimation that arises when all variation in λ is attributed to changes in τ.

The existence of the lens is most easily rationalized by the fact that, at $\lambda = 0.5$, a small tariff has no welfare implications while small iceberg trade costs yield a welfare loss. In contrast, in the neighborhood of autarky (where $\lambda = 1$), things are different. Imagine a further marginal increase in τ. This brings the economy even closer to autarky, but also implies that less resources are lost in transit. In contrast, a further increase in t, which results in the same marginal increase of λ, drives tariff revenue to almost zero. Hence, the absolute value of the slope of the welfare function is higher when t changes than when τ changes.

Figure 1 generalizes easily to the case of asymmetric countries. In such a setup, in all the

[23] We provide formal proofs for the Eaton-Kortum (2002) and the Melitz (2003) model, which respectively nest the Armington model and the Krugman (1980) model.

Figure 1: Gains from trade and share of domestic expenditure: Iceberg trade costs versus tariffs



models considered a strictly positive optimal tariff exists.[24] This means that there is some $\lambda^o \in [0,1]$ that maximizes welfare when openness changes due to t. In other words, the welfare function under variation of t must be concave for a maximum at λ^o to exist. The welfare function under variation of τ remains convex, as before. Hence, a lens opens up and our underestimation result appears.

4 Quantitative exercise

As a final step in this paper, we bring our Propositions 1 and 2 to the data with the aim to quantify the role of tariff income for the size of the gains from trade. We require data on domestic expenditure shares λ_{jj} and on tariff multipliers μ_j for as many countries as possible. We also need to know the iceberg trade cost elasticity ε and the tariff elasticity ζ. To enable comparison with ACR, we stick as close as possible to their quantitative exercise.

ACR suggest to compute λ_{jj} based on import penetration ratios defined as imports over *gross* output rather than GDP. These two measures differ as the former includes imported

[24] See Gros (1987) for the case of the Krugman (1980) model, Alvarez and Lucas (2007) for the Eaton and Kortum (2002) model, and Felbermayr, Jung and Larch (2013) for the Melitz (2003) model.

intermediates while the second does not. Imported intermediates also appear in imports. So, either one computes λ_{jj} based on gross imports and gross output, or on the value added content of imports and GDP.[25] ACR use the former approach. Note that dividing gross imports by GDP would result in lower values of λ_{jj}, leading to overestimation of welfare gains. OECD input-output tables are available for the years 1995, 2000, and 2005. For the year 2000, we have information on gross output from OECD input-output tables for 41 countries.

In a sensitivity analysis, we contrast our results to those based on the value added content of imports in domestic final demand in percent of GDP to compute openness. Data stem from the OECD-WTO Trade in Value Added database which provides information for a subset of 36 countries for the year 2005.

Tariff revenue as a share of gross output is computed from combining trade-weighted average tariffs from the World Development Indicators data base with information on imports and gross output from the input-output tables. For six countries, the year 2000 average tariff is missing. We use the averaged value from the years 1999 and 2001 instead.[26]

Finally, we need information on ε and ζ. Ideally, to obtain estimates for these parameters, we would have data on iceberg trade costs and tariffs. In the cases of the Armington (1969), Krugman (1980) and Eaton and Kortum (2002) models, one would estimate a gravity equation under the assumption $\varepsilon = \zeta$. In the Melitz (2003) case, we have $\varepsilon \neq \zeta$, and so one would have to estimate a gravity model and allow parameters to differ. This paper is not about the consistent estimation of trade elasticities, which is a non-trivial task.[27] Rather, we demonstrate the quantitative importance of taking observed tariffs into account based on estimates taken from the literature and staying as close to ACR as possible. Hence, we set the elasticity to either -5 or -10 when the underlying model mandates $\varepsilon = \zeta$. For the Melitz (2003) model, we use recent estimates by Crozet and Koenig (2010) obtained from structural estimation based on firm-level data. They report an elasticity of substitution of $\sigma = 2.25$ and a Pareto decay parameter of $\theta = 3.09$. These estimates imply $\varepsilon = -3.09$ and $\zeta = -4.562$.

[25] Imports are evaluated at c.i.f. prices (cost, insurance, freight); see OECD Input-Output Database edition 2006 - STI Working Paper 2006/8.

[26] The six countries are: India, Korea, Russian Federation, South Africa, Turkey, and Vietnam.

[27] E.g., one would have to deal with the possibility that tariffs are endogenous.

In our 41 country sample, in the year 2000, import penetration ratios vary between 5.2% in Japan at the lower end to 53.9% in Luxembourg at the higher end. The average is 22.9% and the standard deviation across our country sample is 11.7%.[28] The trade-weighted average import tariff varies between 1.1% in Norway and 27.5% in India. The average tariff rate is 4.2%; the standard deviation is 5.3%. So, in 2000, tariffs are not negligible for a considerable number of countries. Similarly, in the data, there is substantial variation in the share of tariffs in gross output; it ranges between 0.1% (Japan, USA) and Vietnam (5,2%) with a mean of 0.8% and a standard deviation of 0.8%.

The tariff multiplier, computed according to equation (6), ranges from 1.0014 for less open and low-tariff countries like the US and Japan to 1.0548 for Vietnam, a country that, in the year 2000, imposes an import tariff of about 18% but is still relatively open. The mean multiplier is 1.0079 and the standard deviation is 1.0057. The tariff multipliers seem to be very small in size. However, since the gains from trade are rather small as well (as demonstrated by ACR), the amount of underestimation can still be sizeable.

Table 2 reports welfare gains from trade relative to autarky for the models in which iceberg trade cost and tariff elasticities $\varepsilon = \zeta$ coincide. As ACR, we set $\varepsilon \in \{-5, -10\}$. Following ACR, the columns entitled "Icebergs only" assume that, counterfactually, tariff revenue in all countries is zero. Gains from trade therefore can only stem from a reduction in iceberg trade costs. This case yields gains from trade that replicate the findings of ACR for the US and also turn out very small for many other countries. For the conservative case of $\varepsilon = \zeta = -5$, the mean value for the gains from trade is 5.6% with a standard deviation of 3.6%. The columns entitled "Icebergs&tariffs " refer to the situation where tariff revenue, as observed, is taken into account. Gains from trade can originate from a reduction in iceberg trade costs and/or tariffs. As predicted by theory, in this case, the gains from trade are substantially larger: the mean is 6.4% and the standard deviation is 3.9%. The third column reports the degree by which the ACR formula underestimates the true gains from trade. Our exercise suggests that the amount of underestimation can be very substantial: for the case $\varepsilon = \zeta = -5$ it can range as high as 57.7% in India, 45.7% in Vietnam or 41.7% in China. All these countries still have substantial

[28]Table 4 in the Appendix reports the full data.

tariffs in place as of year 2000. The average amount of underestimation is 14.4%; the median is 8.9%.

When ignoring tariffs, the gains from trade fall by about 50% on average relative to the conservative parametrization when a higher trade elasticity of $\varepsilon = \zeta = -10$ is assumed. When taking tariffs into account, the gains are also lower than under the baseline, but by less than 50%. The degree of underestimation goes up substantially in most countries: on average it is now 23.3% instead of 14.4%. The bias appears very in the high-tariff countries discussed above. However, underestimation appears important in some rich countries such as Australia (51.1%), too.

Figure 2 reproduces the ACR welfare formula for $\varepsilon = \zeta = -5$ as a function of λ. It also plots the gains from trade in the presence of tariff revenue for the years of 1995 (filled circles), 2000 (empty circles), and 2005 (asterisks). As tariffs have come down over time, the underestimation implied by the ACR formula has become smaller. The figure also shows that the difference between the situation with iceberg trade costs only and the case with iceberg trade costs and tariffs increases when the domestic expenditure share falls.

Table 3 turns to the case where $\varepsilon \geq \zeta$ such as in the Melitz (2003) model. We employ the parameter estimates provided by Crozet and Koenig (2010) which imply $\varepsilon = -3.09$ and $\zeta = -4.562$. To facilitate comparison, we report welfare gains under the assumption that both elasticities were equal to ε. This special situation reproduces the Krugman (1980) situation as a special case of the Melitz (2003) model. The column entitled "Icebergs only" shows the associated gains when tariff revenue is ignored; the column entitled "Icebergs and tariffs" reports the gains when the observed tariff revenue is taken into account, and the column entitled "underestimation" provides the degree of underestimation incurred. Gains from trade appear generally higher than in Table 2, where a higher trade elasticity ($\varepsilon = -5$) was used. The average amount of underestimation goes down.

The final two columns of Table 3 impose $\varepsilon = -3.09$ and $\zeta = -4.562$. Under this situation, trade responds more strongly to tariffs than to iceberg trade costs. Given observed tariffs, lower levels of iceberg trade costs are required to reproduce observed openness levels. This increases the difference between our calibration and the ACR case with iceberg trade costs only. Hence, in

Table 2: Gains from trade relative to autarky when iceberg trade costs and tariff elasticities coincide (year 2000)

	Trade elasticities: -5			*Trade elasticities:* -10		
	Icebergs only	**Icebergs and tariffs**	**Under-estimation**	**Icebergs only**	**Icebergs and tariffs**	**Under-estimation**
Australia	2.4%	3.6%	34.5%	1.2%	2.4%	51.2%
Austria	6.1%	6.7%	8.8%	3.0%	3.6%	15.9%
Belgium	10.0%	10.9%	8.3%	4.9%	5.7%	15.0%
Brazil	1.4%	2.3%	38.3%	0.7%	1.6%	55.3%
Bulgaria	5.1%	5.6%	8.9%	2.5%	3.0%	16.2%
Canada	5.0%	5.3%	5.6%	2.5%	2.8%	10.5%
China	1.8%	3.0%	41.7%	0.9%	2.1%	58.7%
Cyprus	9.7%	10.5%	8.3%	4.7%	5.6%	15.0%
Czech Republic	6.6%	7.2%	8.7%	3.2%	3.8%	15.8%
Denmark	6.1%	6.7%	8.7%	3.0%	3.6%	15.9%
Estonia	10.6%	11.5%	8.2%	5.2%	6.0%	14.8%
Finland	3.9%	4.3%	9.1%	2.0%	2.3%	16.5%
France	3.4%	3.7%	9.1%	1.7%	2.0%	16.6%
Germany	4.2%	4.6%	9.0%	2.1%	2.5%	16.4%
Greece	5.7%	6.2%	8.8%	2.8%	3.3%	16.0%
Hungary	9.2%	10.0%	8.4%	4.5%	5.3%	15.1%
India	1.7%	4.0%	57.7%	0.8%	3.1%	73.1%
Indonesia	3.5%	4.3%	19.6%	1.7%	2.6%	32.5%
Ireland	11.5%	12.5%	8.1%	5.6%	6.5%	14.6%
Italy	2.9%	3.2%	9.2%	1.5%	1.8%	16.8%
Japan	1.1%	1.2%	12.1%	0.5%	0.7%	21.6%
Korea	4.0%	5.1%	21.6%	2.0%	3.1%	35.3%
Luxembourg	16.7%	18.1%	7.5%	8.0%	9.3%	13.5%
Malta	16.5%	17.9%	7.5%	7.9%	9.2%	13.6%
Netherlands	8.3%	9.1%	8.5%	4.1%	4.8%	15.3%
New Zealand	3.3%	3.6%	10.4%	1.6%	2.0%	18.7%
Norway	4.0%	4.2%	4.7%	2.0%	2.2%	8.9%
Poland	3.9%	4.3%	9.1%	2.0%	2.3%	16.5%
Portugal	5.0%	5.5%	8.9%	2.5%	2.9%	16.2%
Romania	4.6%	5.0%	9.0%	2.3%	2.7%	16.3%
Russian Fed.	3.1%	4.4%	29.6%	1.6%	2.8%	45.5%
Slovak Republic	7.8%	8.5%	8.5%	3.8%	4.5%	15.5%
Slovenia	7.1%	7.8%	8.6%	3.5%	4.2%	15.6%
South Africa	3.1%	3.9%	18.4%	1.6%	2.3%	30.9%
Spain	3.8%	4.2%	9.1%	1.9%	2.2%	16.5%
Sweden	4.9%	5.4%	8.9%	2.4%	2.9%	16.2%
Switzerland	5.3%	5.6%	5.9%	2.6%	2.9%	11.0%
Turkey	3.7%	4.7%	20.1%	1.8%	2.8%	33.2%
United Kingdom	3.5%	3.9%	9.1%	1.8%	2.1%	16.6%
United States	1.6%	1.8%	8.0%	0.8%	0.9%	14.8%
Vietnam	7.0%	12.8%	45.7%	3.4%	9.1%	62.3%
Mean	5.6%	6.4%	14.4%	2.7%	3.6%	23.3%
Median	4.6%	5.1%	8.9%	2.3%	2.9%	16.2%
Std. Dev.	3.6%	3.9%	12.3%	1.7%	2.1%	15.8%

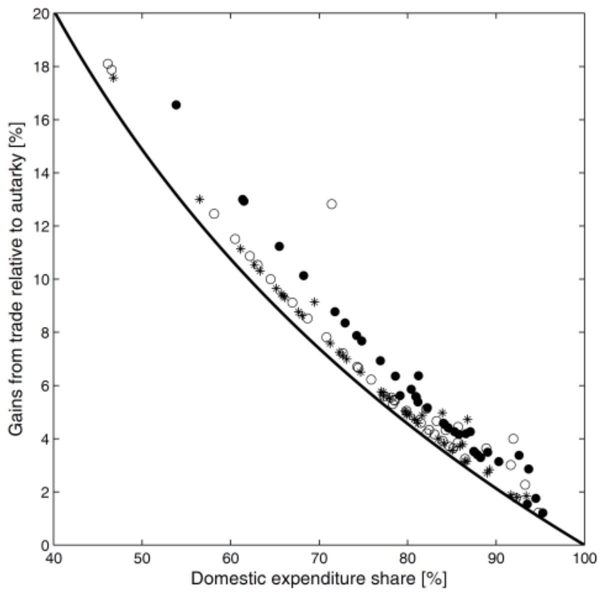
Icebergs only: Gains from trade stem from a pure reduction of iceberg trade costs. **Icebergs and tariffs**: Gains from trade stem from a reduction of iceberg trade costs and/or tariffs that is consistent with observed shares of tariff revenue in GDP. **Underestimation**: Percentage amount of underestimation of Icebergs only relative to Icebergs and tariffs. In the conservative specification (Trade elasticities: -5), the iceberg only formula underestimates gains from trade by 4.7% for Norway to 57.7% for India.

Table 3: Gains from trade relative to autarky when iceberg trade cost and tariff elasticities differ (year 2000).

	Iceberg trade cost elasticity: -3.09				
		Tariff elasticity: -3.09		*Tariff elasticity:* -4.562	
	Icebergs only	**Icebergs and tariffs**	**Under-estimation**	**Icebergs and tariffs**	**Under-estimation**
Australia	3.9%	5.2%	24.7%	5.8%	32.7%
Austria	10.0%	10.6%	5.7%	10.9%	8.2%
Belgium	16.6%	17.6%	5.4%	18.0%	7.8%
Brazil	2.3%	3.2%	27.8%	3.6%	36.3%
Bulgaria	8.3%	8.8%	5.8%	9.1%	8.3%
Canada	8.2%	8.5%	3.6%	8.7%	5.2%
China	2.9%	4.1%	30.8%	4.7%	39.7%
Cyprus	16.1%	17.0%	5.4%	17.5%	7.8%
Czech Republic	10.9%	11.5%	5.7%	11.8%	8.1%
Denmark	10.1%	10.7%	5.7%	11.0%	8.2%
Estonia	17.7%	18.7%	5.4%	19.1%	7.8%
Finland	6.4%	6.9%	5.9%	7.0%	8.4%
France	5.5%	5.8%	5.9%	6.0%	8.5%
Germany	6.8%	7.3%	5.8%	7.5%	8.4%
Greece	9.3%	9.9%	5.7%	10.2%	8.2%
Hungary	15.2%	16.1%	5.5%	16.5%	7.9%
India	2.8%	5.1%	45.8%	6.2%	55.7%
Indonesia	5.7%	6.6%	13.2%	7.0%	18.3%
Ireland	19.2%	20.3%	5.3%	20.8%	7.7%
Italy	4.8%	5.1%	5.9%	5.3%	8.5%
Japan	1.7%	1.9%	7.9%	2.0%	11.2%
Korea	6.6%	7.7%	14.7%	8.3%	20.3%
Luxembourg	28.5%	30.0%	5.0%	30.7%	7.2%
Malta	28.1%	29.6%	5.0%	30.3%	7.2%
Netherlands	13.8%	14.7%	5.5%	15.0%	8.0%
New Zealand	5.3%	5.7%	6.7%	5.9%	9.7%
Norway	6.6%	6.8%	3.0%	6.9%	4.4%
Poland	6.5%	6.9%	5.9%	7.0%	8.4%
Portugal	8.2%	8.7%	5.8%	8.9%	8.3%
Romania	7.5%	8.0%	5.8%	8.2%	8.4%
Russian Fed.	5.1%	6.5%	20.8%	7.1%	28.0%
Slovak Republic	12.9%	13.7%	5.6%	14.0%	8.0%
Slovenia	11.8%	12.5%	5.6%	12.8%	8.1%
South Africa	5.1%	5.9%	12.3%	6.2%	17.2%
Spain	6.2%	6.6%	5.9%	6.8%	8.4%
Sweden	8.1%	8.6%	5.8%	8.9%	8.3%
Switzerland	8.7%	9.0%	3.8%	9.2%	5.5%
Turkey	6.1%	7.1%	13.6%	7.5%	18.8%
United Kingdom	5.8%	6.2%	5.9%	6.3%	8.5%
United States	2.6%	2.8%	5.1%	2.9%	7.4%
Vietnam	11.5%	17.6%	34.7%	20.6%	44.3%
Mean	9.3%	10.1%	10.0%	10.5%	13.6%
Median	7.5%	8.0%	5.8%	8.3%	8.3%
Std. Dev.	6.1%	6.4%	9.6%	6.6%	11.9%

Icebergs only: Gains from trade stem from a pure reduction of iceberg trade costs. **Icebergs and tariffs**: Gains from trade stem from a reduction of iceberg trade costs and/or tariffs that is consistent with observed shares of tariff revenue in GDP. **Underestimation**: Percentage amount of underestimation of Icebergs only relative to Icebergs and tariffs. In all columns, we set $\theta = 3.09$, which implies a *iceberg trade cost elasticity* of $\varepsilon = -3.09$. We set $\sigma = 4.09$ to obtain a *tariff elasticity* of $\zeta = -3.09$ and $\sigma = 2.25$ implying a *tariff elasticity* of $\zeta = -4.562$; see Crozet and Koenig (2010) for empirical evidence on $\theta = 3.09$ and $\sigma = 2.25$. In the latter specification, the iceberg only formula underestimates gains from trade by 4.4% for Norway to 55.7% for India.

Figure 2: Gains from trade relative to autarky: Icebergs only versus icebergs and tariffs



Icebergs only: Gains from trade stem from a pure reduction of iceberg trade costs. **Icebergs and tariffs**: Gains from trade stem from a reduction of iceberg trade costs and/or tariffs that is consistent with observed shares of tariff revenue in GDP. Data are given for the years 1995 (filled circles), 2000 (empty circles), and 2005 (asterisks).

the Melitz (2003) model, the approximation achieved from focusing on iceberg trade costs alone is more inaccurate than in the other models considered. The average degree of underestimation is about 13%, with peaks in countries such as India of more than 55%.

So far, results are based on import penetration ratios computed as imports over gross output. An alternative route is to make use of the foreign value added content of imports in percent of GDP. Table 5 in the Appendix contrasts these approaches for the year 2005 and for a specification in which iceberg and tariff elasticities differ. In the year 2005, the mean tariff rate is about 2.8%, which is considerably smaller than in 2000 (4.2%). In the majority of cases, the valued added approach implies a larger degree of opennes and therefore a smaller domestic expenditure share λ_{jj}. Accordingly, welfare gains are typically larger under the value added approach than under the imports approach. Moreover, the bias of the ACR formula is smaller (8.7% versus 10.1%), which is in line with part (a) of Proposition 2.

5 Conclusion

In this paper, we have revisited the welfare gains from trade for new trade models in the presence of revenue generating ad valorem tariffs. Thereby, we extend the analysis of Arkolakis et al. (ACR, 2012). We show analytically that the ex post gains from trade can be easily calculated from data on the domestic expenditure and the share of tariff revenue in total income of a country. Also, one needs estimates of the elasticities of trade flows with respect to iceberg trade costs and tariffs. When these two elasticities coincide, the gains from trade do not depend on the micro structure. However, in on leading model, the Melitz (2003) framework, the elasticities differ. Given trade and tariff data, it follows that the welfare gains are larger in the Melitz (2003) model than in other models (e.g., the Armington (1969), Krugman (1980) and Eaton and Kortum (2002) models).

For all the considered new trade models, we find that neglecting tariff revenue necessarily leads to an underestimation of the welfare gains from trade relative to autarky. The bias is largest in economies characterized by high tariff revenue and high domestic expenditure shares. For a sample of 41 countries observed at the year of 2000, we find that ignoring tariffs leads to an underestimation of the true gains by 13-23% on average. This hides substantial cross-sectional variance. The underestimation can be higher than 30% for Australia, but can be below 5% for a country such as Norway.

Our results highlight the need for further research on at least two fronts. First, the structural estimation of welfare gains in new trade models requires unbiased and consistent estimates of both iceberg trade cost and tariff elasticities. Theory-consistent econometric exercises are still rare and plagued by problems such as the lack of observability of iceberg trade costs and possible endogeneity of average tariff rates. Second, the important differences between iceberg trade cost and tariff frictions suggest that other alternative trade policy instruments such as export subsidies may have important welfare consequences, too.

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A Additional tables

Table 4: Country characteristics for the year 2000.

	Openness	**Tariff rate**	**Tariff revenue**	**Multiplier**
Australia	11.1%	10.9%	1.2%	1.012
Austria	25.6%	2.1%	0.5%	1.005
Belgium	37.8%	2.1%	0.8%	1.008
Brazil	6.7%	12.7%	0.8%	1.009
Bulgaria	21.9%	2.1%	0.5%	1.005
Canada	21.7%	1.3%	0.3%	1.003
China	8.3%	14.6%	1.2%	1.012
Cyprus	36.9%	2.1%	0.8%	1.008
Czech Republic	27.3%	2.1%	0.6%	1.006
Denmark	25.7%	2.1%	0.5%	1.006
Estonia	39.5%	2.1%	0.8%	1.009
Finland	17.6%	2.1%	0.4%	1.004
France	15.2%	2.1%	0.3%	1.003
Germany	18.5%	2.1%	0.4%	1.004
Greece	24.1%	2.1%	0.5%	1.005
Hungary	35.5%	2.1%	0.8%	1.008
India	8.0%	27.5%	2.2%	1.023
Indonesia	15.7%	5.2%	0.8%	1.008
Ireland	41.9%	2.1%	0.9%	1.009
Italy	13.5%	2.1%	0.3%	1.003
Japan	5.2%	2.8%	0.1%	1.001
Korea	17.9%	5.9%	1.1%	1.011
Luxembourg	53.9%	2.1%	1.2%	1.012
Malta	53.5%	2.1%	1.1%	1.012
Netherlands	33.0%	2.1%	0.7%	1.007
New Zealand	14.8%	2.5%	0.4%	1.004
Norway	17.8%	1.1%	0.2%	1.002
Poland	17.6%	2.1%	0.4%	1.004
Portugal	21.5%	2.1%	0.5%	1.005
Romania	20.1%	2.1%	0.4%	1.004
Russian Fed.	14.3%	8.8%	1.3%	1.013
Slovak Republic	31.3%	2.1%	0.7%	1.007
Slovenia	29.2%	2.1%	0.6%	1.006
South Africa	14.3%	4.8%	0.7%	1.007
Spain	17.0%	2.1%	0.4%	1.004
Sweden	21.4%	2.1%	0.5%	1.005
Switzerland	22.7%	1.4%	0.3%	1.003
Turkey	16.7%	5.4%	0.9%	1.009
United Kingdom	16.0%	2.1%	0.3%	1.003
United States	7.7%	1.8%	0.1%	1.001
Vietnam	28.6%	18.2%	5.2%	1.055
Mean	22.6%	4.3%	0.8%	1.008
Median	20.1%	2.1%	0.6%	1.006
Std. Dev.	11.7%	5.3%	0.8%	0.009

Notes: **Openness**: Constructed from the OECD Input-Output Database as imports over gross output; see ACR. **Tariff rates**: Trade-weighted average tariff rates come from World Development Indicators. For India, Korea, Russian Federation, South Africa, Turkey, and Vietnam, tariff rates are missing for the year 2000 and are replaced by average tariff rates for the years 1999 and 2001. **Tariff revenue**: Tariff revenue as a percentage of gross output. **Tariff multiplier**: Calculated from the tariff revenue share; see equation (6).

Table 5: Sensitivity analysis: Different measures of openness (year 2005).

	Tariff rate	**Tariff revenue**	**Openness**		**Icebergs only**		**Icebergs and tariffs**		**Under-estimation**	
			Imports	*VA*	*Imports*	*VA*	*Imports*	*VA*	*Imports*	*VA*
Australia	3.1%	0.3%	11.0%	17.3%	3.9%	6.4%	4.4%	6.9%	11.9%	7.7%
Austria	1.8%	0.5%	27.3%	25.5%	10.9%	10.0%	11.7%	10.8%	7.1%	7.6%
Belgium	1.8%	0.7%	36.7%	27.7%	15.9%	11.1%	17.1%	12.2%	6.8%	9.2%
Brazil	7.1%	0.5%	6.6%	8.8%	2.2%	3.0%	2.9%	3.8%	24.1%	19.0%
Canada	1.5%	0.3%	20.1%	22.4%	7.5%	8.5%	8.0%	9.0%	5.8%	5.2%
Chile	3.9%	0.7%	18.4%	25.2%	6.8%	9.8%	7.9%	11.0%	14.2%	10.5%
China	4.8%	0.5%	10.8%	17.1%	3.8%	6.2%	4.6%	7.1%	17.6%	11.6%
Czech Republic	1.8%	0.5%	27.7%	32.4%	11.1%	13.5%	11.9%	14.3%	7.1%	6.0%
Denmark	1.8%	0.5%	26.9%	22.7%	10.7%	8.7%	11.5%	9.5%	7.1%	8.4%
Estonia	1.8%	0.7%	38.9%	42.4%	17.3%	19.6%	18.5%	20.8%	6.7%	6.1%
Finland	1.8%	0.4%	19.2%	21.9%	7.2%	8.3%	7.7%	8.9%	7.3%	6.4%
France	1.8%	0.3%	14.9%	18.3%	5.4%	6.7%	5.8%	7.2%	7.4%	6.1%
Germany	1.8%	0.4%	19.8%	18.7%	7.4%	6.9%	8.0%	7.5%	7.3%	7.7%
Greece	1.8%	0.4%	20.3%	25.0%	7.6%	9.8%	8.2%	10.4%	7.3%	5.9%
Hungary	1.8%	0.6%	32.3%	30.5%	13.5%	12.5%	14.5%	13.5%	6.9%	7.4%
India	13.4%	1.8%	13.2%	16.9%	4.7%	6.2%	7.5%	9.0%	37.3%	31.5%
Indonesia	4.4%	0.6%	14.1%	22.8%	5.0%	8.7%	6.0%	9.7%	16.1%	10.3%
Ireland	1.8%	0.6%	34.0%	28.9%	14.4%	11.7%	15.5%	12.7%	6.9%	8.2%
Israel	1.7%	0.4%	23.0%	24.7%	8.8%	9.6%	9.4%	10.2%	6.5%	6.0%
Italy	1.8%	0.2%	13.3%	16.8%	4.7%	6.1%	5.1%	6.5%	7.4%	5.9%
Japan	2.5%	0.2%	7.6%	10.2%	2.6%	3.5%	2.9%	3.8%	10.0%	7.7%
Korea	8.3%	1.3%	16.1%	21.2%	5.8%	8.0%	8.0%	10.2%	26.7%	21.3%
Luxembourg	1.8%	1.0%	53.2%	35.9%	27.9%	15.5%	29.8%	17.1%	6.3%	9.9%
Netherlands	1.8%	0.6%	33.9%	20.0%	14.3%	7.5%	15.4%	8.5%	6.9%	11.7%
Norway	1.7%	0.3%	18.8%	20.5%	7.0%	7.7%	7.5%	8.2%	6.7%	6.2%
Poland	1.8%	0.4%	19.0%	24.8%	7.1%	9.7%	7.6%	10.2%	7.3%	5.6%
Portugal	1.8%	0.4%	20.2%	26.9%	7.6%	10.7%	8.1%	11.3%	7.3%	5.4%
Slovak Republic	1.8%	0.6%	34.8%	40.9%	14.9%	18.5%	16.0%	19.7%	6.9%	5.8%
Slovenia	1.8%	0.6%	31.9%	32.2%	13.3%	13.4%	14.2%	14.4%	6.9%	6.9%
South Africa	5.5%	0.8%	13.8%	20.6%	4.9%	7.8%	6.1%	9.0%	19.3%	13.5%
Spain	1.8%	0.3%	15.9%	20.4%	5.8%	7.7%	6.2%	8.1%	7.4%	5.7%
Sweden	1.8%	0.4%	22.0%	21.9%	8.4%	8.3%	9.0%	9.0%	7.2%	7.3%
Switzerland	1.3%	0.3%	22.7%	25.6%	8.7%	10.1%	9.2%	10.5%	5.1%	4.5%
Turkey	1.5%	0.2%	13.5%	18.9%	4.8%	7.0%	5.1%	7.3%	6.1%	4.4%
United Kingdom	1.8%	0.3%	16.5%	21.3%	6.0%	8.1%	6.5%	8.5%	7.4%	5.7%
United States	1.6%	0.1%	8.3%	12.6%	2.9%	4.4%	3.1%	4.6%	6.6%	4.4%
Mean	2.8%	0.5%	21.6%	23.3%	8.6%	9.2%	9.5%	10.0%	10.1%	8.7%
Median	1.8%	0.4%	19.5%	22.2%	7.3%	8.4%	8.0%	9.2%	7.2%	7.1%
Std. Dev.	2.4%	0.3%	10.2%	7.4%	5.2%	3.6%	5.4%	3.8%	7.0%	5.4%

Imports: Openness measured as imports over gross output from input-output tables as in ACR. *VA*: Openness measured as foreign value added embodied in domestic final demand in percent of GDP. **Icebergs only**: Gains from trade stem from a pure reduction of iceberg trade costs. **Icebergs and tariffs**: Gains from trade stem from a reduction of iceberg trade costs and/or tariffs that is consistent with observed shares of tariff revenue in GDP. **Underestimation**: Percentage amount of underestimation of Icebergs only relative to Icebergs and tariffs. We set $\theta = 3.09$ and $\sigma = 2.25$, which implies a iceberg trade cost elasticity of $\varepsilon = -3.09$ and a tariff elasticity of $\zeta = -4.562$; see Crozet and Koenig (2010) for empirical evidence on θ and σ.

B Gravity

With preferences given by a symmetric CES aggregator function with elasticity of substitution $\sigma > 1$, expenditure $x_{ij}(\omega)$ for a given variety ω from country i in country j is given by

$$x_{ij}(\omega) = \left[\frac{p_{ij}(\omega)}{P_j}\right]^{1-\sigma} X_j,$$

where $p_{ij}(\omega)$ is the c.i.f. price such that $p_{ij}(\omega) = p_i \tau_{ij} t_{ji}$. We assume linear technologies such that variable production cost per unit of output in country i is given by $w_i/\varphi(\omega)$.

B.1 Armington

Perfect competition and identical linear technology $\varphi(\omega) = 1$ across varieties such that $p_i(\omega) = w_i$. If country i produces N_i varieties, then

$$\frac{X_{ij}}{X_{jj}} = \frac{N_i}{N_j}\left(\frac{w_i}{w_j}\right)^{1-\sigma}(\tau_{ij}t_{ji})^{1-\sigma}. \tag{17}$$

Note that, different to the standard treatment, τ_{ij} and t_{ji} have the same elasticities $\varepsilon = \zeta = 1-\sigma$ because trade flows are defined inclusive of tariff payments.

B.2 Eaton-Kortum

In a perfect competition Ricardian trade model with a continuum of varieties à la Eaton-Kortum (2002), each countries productivity φ in producing a variety ω is Fréchet distributed with $F(\varphi) = \exp(-T_i\varphi^{-\gamma})$, where $T_i \geq 1$ measures the location (country $i's$ lowest possibly productivity draw) the location and γ the shape of the distribution. That model admits a gravity equation of the form

$$\frac{X_{ij}}{X_{jj}} = \frac{T_i}{T_j}\left(\frac{w_i}{w_j}\right)^{-\gamma}(\tau_{ij}t_{ji})^{-\gamma}. \tag{18}$$

Again, τ_{ij} and t_{ji} have the same elasticities $\varepsilon = \zeta = -\gamma$.

B.3 Melitz

Firms differ with respect to productivity φ which, in line with the literature, is assumed to follow a Pareto distribution with c.d.f. $G_i(\varphi) = 1 - (\varphi/b_i)^{-\theta}$, where b_i governs location and θ is the shape of the distribution. Presence of a firm from i on a market j requires payment of fixed costs $w_j f_{ij}$ in terms of labor from the destination country j. Only firms with $\varphi \geq \varphi^*_{ij}$ will be earning sufficiently much revenue on market j to support market presence in the presence of fixed access costs. Under these conditions the gravity equation is given by

$$\frac{X_{ij}}{X_{jj}} = \frac{N_i}{N_j}\left(\frac{b}{b_j}\right)^{\theta}\left(\frac{f_{ij}}{f_{jj}}\right)^{1-\frac{\theta}{\sigma-1}}\left(\frac{w_i}{w_j}\right)^{-\theta}\tau_{ij}^{-\theta}t_{ji}^{1-\theta/\rho}. \tag{19}$$

The mass of potential entrants N_i and N_j are solved via a free-entry condition and turn out independent from trade costs (t_{ji}, τ_{ji}) and wages. Hence, in the Melitz case with Pareto-distributed productivity, $\varepsilon = -\theta$ and $\zeta = 1-\theta/\rho$. Letting $\theta \to \sigma - 1$ to close down the selection effect, the Melitz gravity equation (19) collapses to the Krugman form with $\varepsilon = \zeta = 1-\sigma$.

C Derivation of equation (11)

Armington. The domestic expenditure share is given by

$$\lambda_{jj} = \frac{1}{1+\sum\limits_{i\neq j}\frac{X_{ij}}{X_{jj}}} = \frac{1}{1+\sum\limits_{i\neq j}\frac{N_i}{N_j}\left(\frac{w_i}{w_j}\tau_{ij}t_{ji}\right)^{1-\sigma}},$$

which follows from the gravity equation given in (17). The price index reads

$$P_j^{1-\sigma} = N_j w_j^{1-\sigma}\left\{1+\sum_{i\neq j}\frac{N_i}{N_j}\left(\frac{w_i}{w_j}\tau_{ij}t_{ji}\right)^{1-\sigma}\right\}.$$

Using the expression for the domestic expenditure share to substitute out the term in curly brackets and rearranging terms, we obtain

$$\frac{w_j}{P_j} = N_j \lambda_{jj}^{-\frac{1}{\sigma-1}}.$$

Equation (11) follows from noting that $\varepsilon = \zeta = 1-\sigma$ and noting that N_j is independent of trade costs.

Eaton-Kortum. Using equation (18), we can write the domestic expenditure share as

$$\lambda_{jj} = \frac{1}{1+\sum\limits_{i\neq j}\frac{T_i}{T_j}\left(\frac{wi}{w_j}\right)^{-\gamma}(\tau_{ij}t_{ji})^{-\gamma}}.$$

The price index reads

$$\left(\frac{w_j}{P_j}\right)^{\gamma} = \kappa^{-\gamma}T_j\left\{1+\sum_{i\neq j}\frac{T_i}{T_j}\left(\frac{w_i}{w_j}\right)^{-\gamma}(\tau_{ij}t_{ji})^{-\gamma}\right\},$$

where $\kappa \equiv \left(\Gamma\left[\frac{\gamma-(\sigma-1)}{\gamma}\right]\right)^{-1/(\sigma-1)}$ with $\Gamma[.]$ denoting the Gamma function. Again, equation (11) follows from using the expression for the domestic expenditure share to substitute out the terms in curly brackets and rearranging terms.

Melitz. Using equation (19), we can write the domestic expenditure share as

$$\lambda_{jj} = \frac{1}{1 + \sum_{i \neq j} \frac{N_i}{N_j} \left(\frac{b_i}{b_j}\right)^{\theta} \left(\frac{f_{ij}}{f_{jj}}\right)^{1-\frac{\theta}{\sigma-1}} \left(\frac{w_i}{w_j}\right)^{-\theta} \tau_{ij}^{-\theta} t_{ji}^{1-\theta/\rho}}.$$

The price index is given as

$$P_j^{1-\sigma} = \frac{\theta}{\theta-(\sigma-1)} \sum_i \left(\varphi_{ij}^*\right)^{-\theta} N_i b_i^{\theta} \left(\frac{\rho \varphi_{ij}^*}{\tau_{ij} t_{ji} w_i}\right)^{\sigma-1},$$

where $\left(\frac{\varphi_{ij}^*}{\varphi_{ii}^*}\right)^{-\theta} \left(\frac{\varphi_{ii}^*}{b_i}\right)^{-\theta} N_i = \left(b_i/\varphi_{ij}^*\right)^{\theta} N_i$ represents the mass of firms from country i active in j conditional on successful entry into existence, and where the zero profit cutoff productivities φ_{ij}^* are given by

$$X_j P_j^{\sigma-1} t_{ji}^{-1} \left(\frac{\rho \varphi_{ij}^*}{\tau_{ij} t_{ji} w_i}\right)^{\sigma-1} = \sigma w_j f_{ij}.$$

Using this expression, we can rewrite the price index as

$$1 = \frac{\theta\sigma}{\theta-(\sigma-1)} \frac{w_j}{X_j} \sum_i \left(\varphi_{ij}^*\right)^{-\theta} N_i b_i^{\theta} f_{ij} t_{ji}.$$

Making again use of the zero profit cutoff condition, we obtain

$$\left(\frac{w_j}{P_j}\right)^{\theta} = \frac{\theta \sigma^{1-\frac{\theta}{\sigma-1}} \rho^{\theta}}{\theta-(\sigma-1)} N_j b_j^{\theta} f_{jj}^{1-\frac{\theta}{\sigma-1}} \left(\frac{w_j}{X_j}\right)^{1-\frac{\theta}{\sigma-1}} \left(1 + \sum_{i \neq j} \frac{N_i}{N_j} \left(\frac{b_i}{b_j}\right)^{\theta} \left(\frac{f_{ij}}{f_{jj}}\right)^{1-\frac{\theta}{\sigma-1}} \left(\frac{w_i}{w_j}\right)^{-\theta} \tau_{ij}^{-\theta} t_{ji}^{1-\frac{\theta}{\rho}}\right).$$

Recalling that $w_j L_j / X_j = \mu_j^{-1}$ and using the expression of the domestic expenditure share, we obtain

$$\frac{w_j}{P_j} = \left(\frac{\theta \sigma^{1-\frac{\theta}{\sigma-1}} \rho^{\theta}}{\theta-(\sigma-1)} N_j b_j^{\theta} f_{jj}^{1-\frac{\theta}{\sigma-1}} L_j^{\frac{\theta}{\sigma-1}-1}\right)^{\frac{1}{\theta}} \mu_j^{\frac{\theta-(\sigma-1)}{\theta(\sigma-1)}} \lambda_{jj}^{-\frac{1}{\theta}}.$$

Equation (11) follows from noting that $\varepsilon = -\theta$ and $\zeta = 1 - \theta/\rho$.

D Decomposition of trade elasticities in Melitz

Aggregate imports can be written as $X_{ij} = N_{ij}\bar{x}_{ij}$, where $N_{ij} = \left(1 - G\left[\varphi_{ij}^*\right]\right) N_i$ is the mass of foreign exporters and and $\bar{x}_{ij} \equiv \int_{\varphi_{ij}^*}^{\infty} x_{ij}\left[\varphi\right] \frac{g[\varphi]}{1-G\left[\varphi_{ij}^*\right]} d\varphi$ is average expenditure on imported varieties. Following Head and Mayer (2013), the change in imports can be written as:[29]

$$\begin{aligned}\frac{d\ln X_{ij}}{d\ln \tau_{ij}} &= \underbrace{\frac{1}{\bar{x}_{ij}}\left(\int_{\varphi_{ij}^*}^{\infty} x_{ij}\left[\varphi\right]\frac{d\ln x_{ij}\left[\varphi\right]}{d\ln\tau_{ij}}\frac{g\left[\varphi\right]}{1-G\left[\varphi_{ij}^*\right]}d\varphi\right)}_{\text{intensive margin}} \\ &+ \underbrace{\frac{d\ln N_{ij}}{d\ln\tau_{ij}}}_{\text{ext. margin}} + \underbrace{\frac{d\ln\left(1-G\left[\varphi_{ij}^*\right]\right)}{d\ln\varphi_{ij}^*}\frac{d\ln\varphi_{ij}^*}{d\ln\tau_{ij}}\left(\frac{x_{ij}\left[\varphi_{ij}^*\right]}{\bar{x}_{ij}} - 1\right)}_{\text{compositional margin}}. \end{aligned} \tag{20}$$

The *extensive margin* is the change in the mass of foreign exporters:

$$\frac{d\ln N_{ij}}{d\ln\tau_{ij}} = \frac{d\ln\left(1-G\left[\varphi_{ij}^*\right]\right)}{d\ln\varphi_{ij}^*}\frac{d\ln\varphi_{ij}^*}{d\ln\tau_{ij}} = -\theta\frac{d\ln\varphi_{ij}^*}{d\ln\tau_{ij}},$$

where the second equality follows from Pareto. The *intensive margin* is defined as the change in expenditure on already existing varieties. With CES preferences, expenditure in country j on a variety φ from country i is given by

$$x_{ij}\left[\varphi\right] = \left(\frac{w_i\tau_{ij}t_{ji}}{\rho\varphi P_j}\right)^{1-\sigma} X_j. \tag{21}$$

Hence, the intensive margin is given by $1-\sigma$.[30]

With Pareto, expenditure on the cutoff firm relative to average expenditure is given by

$$\frac{x_{ij}\left[\varphi_{ij}^*\right]}{\bar{x}_{ij}} = \frac{\theta-(\sigma-1)}{\theta}.$$

Summarizing these observations, we obtain

$$\frac{d\ln X_{ij}}{d\ln\tau_{ij}} = \underbrace{1-\sigma}_{\text{intensive margin}} - \underbrace{\theta\frac{d\ln\varphi_{ij}^*}{d\ln\tau_{ij}}}_{\text{extensive margin}} + \underbrace{(\sigma-1)\frac{d\ln\varphi_{ij}^*}{d\ln\tau_{ij}}}_{\text{compositional margin}}.$$

[29] We index firms by their productivity φ, wheras Head and Mayer (2013) index firms by their unit input coefficients $1/\varphi$. Note that the trade elasticities reflect partial effects. In Head and Mayer (2013), wages, aggregate spending, and the price index are hold constant. Aggregate spending and the price index drop from the gravity restriction (R3') as we consider relative imports.

[30] The trade elasticities reflect partial effects. In Head and Mayer (2013), wages, aggregate spending, and the price index are hold constant. Aggregate spending and the price index drop from the gravity restriction (R3') as we consider relative imports.

This expression can be extented to cover the case of tariffs. As we define imports inclusive of tariffs, the intensive margin is the same for iceberg trade costs and tariffs.[31] The key difference is the effect of trade costs on the import cutoff.

In order to hold profits constant, an increase in iceberg trade costs leads to a proportionate increase in the import cutoff:

$$\frac{d\ln\varphi_{ij}^{*}}{d\ln\tau_{ij}} = 1.$$

Hence, the intensive and the compositional margin exactly cancel out, and the elasticity of imports with respect to iceberg trade costs simplifies to

$$\varepsilon \equiv \frac{d\ln X_{ij}}{d\ln\tau_{ij}} = -\theta.$$

Consider now the case of tariffs. The zero cutoff profit condition is given by

$$X_j P_j^{\sigma-1} t_{ji}^{-1}\left(\frac{\rho\varphi_{ij}}{\tau_{ij}t_{ji}w_i}\right)^{\sigma-1} = \sigma w_j f_{ij}, \tag{22}$$

which implies that the response of the import cutoff to a change in tariffs is more than proportional:[32]

$$\frac{d\ln\varphi_{ij}^{*}}{d\ln t_{ji}} = \frac{\sigma}{\sigma-1}.$$

As in the case of iceberg trade costs, an increase in the tariff raises the consumer price $p_{ij} = p_i\tau_{ij}t_{ji}$ and therefore lowers demand and revenue. In the case of iceberg trade costs, there is a countervailing effect which is not present in the case of tariffs. For given demand, an increase in τ_{ij} means that the firm has higher revenue as it sells τ_{ij} units per unit exported.

$$\begin{aligned} r_{ij}[\varphi] &= \tau_{ij}p_i[\varphi]\times q_{ij}[\varphi] - w_i \times \frac{\tau_{ij}q_{ij}[\varphi]}{\varphi} \\ &= X_j P_j^{\sigma-1}t_{ji}^{-1}\left(\frac{\rho\varphi_{ij}}{\tau_{ij}t_{ji}w_i}\right)^{\sigma-1}. \end{aligned}$$

Combining these observations, the elasticity of imports with respect to tariffs is given by

$$\zeta \equiv \frac{d\ln X_{ij}}{d\ln t_{ji}} = 1-\sigma-\theta\frac{\sigma}{\sigma-1} + (\sigma-1)\frac{\sigma}{\sigma-1} = 1 - \frac{\theta\sigma}{\sigma-1}.$$

[31] In this respect, the Melitz (2003) resembles the other quantitative trade models that we consider which do not feature a firm extensive margin.

[32] Importantly, the partial effect of tariffs on imports does not depend on whether fixed export cost are paid in domestic or foreign labor. If exporting and importing matter, the right hand side of equation (22) reads $\sigma w_i^{\alpha} w_j^{1-\alpha} f_{ij}$. The expression in equation (22) is nested for $\alpha = 0$.

E Proof of proposition 2

For simplicity we suppress country indices in this Appendix. We can do so without causing confusion because we refer only to domestic variables. We calculate derivatives of a function that contains absolute values, which are given by $\frac{\partial}{\partial x}|u| = \frac{u}{|u|}u'$.

Part (a). Taking the first derivative of κ with respect to λ for given μ and with respect to μ for given λ, we obtain

$$\begin{aligned}\frac{\partial \kappa}{\partial \lambda} &= -\frac{100\lambda^{\frac{1}{\varepsilon}-1}\left(\mu^{\frac{\zeta}{\varepsilon}}-1\right)}{\varepsilon\left(\mu^{\frac{\zeta}{\varepsilon}}\lambda^{\frac{1}{\varepsilon}}-1\right)^2} > 0,\\ \frac{\partial \kappa}{\partial \mu} &= \frac{\zeta}{\varepsilon}\frac{100\lambda^{\frac{1}{\varepsilon}}\left(\lambda^{\frac{1}{\varepsilon}}-1\right)\mu^{\frac{\zeta}{\varepsilon}-1}}{\left(\mu^{\frac{\zeta}{\varepsilon}}\lambda^{\frac{1}{\varepsilon}}-1\right)^2} > 0,\end{aligned}$$

which proves part (a) of the proposition.

Part (b). Let $\varepsilon = \zeta$. Taking the first derivative of κ with respect to ε for given λ and μ, we obtain

$$\left.\frac{\partial \kappa}{\partial \varepsilon}\right|_{\varepsilon=\zeta} = -\frac{100\,(\mu-1)\,\lambda^{\frac{1}{\varepsilon}}\ln\lambda}{\varepsilon^2\left(\mu\lambda^{\frac{1}{\varepsilon}}-1\right)^2} \leq 0,$$

where the inequality strictly holds if $\mu > 1$. This proves part (b) of the proposition.

Part (c). Let $\varepsilon = -\theta$ and $\zeta = 1 - \theta/\rho$. Taking the first derivative of κ with respect to θ and ρ for given λ and μ, we obtain

$$\begin{aligned}\frac{\partial \kappa}{\partial \theta} &= 100\mu^{\frac{1}{\theta}}\frac{\lambda^{\frac{1}{\theta}}\left(\mu^{\frac{1}{\theta}}-\mu^{\frac{1}{\rho}}\right)\ln\lambda + \mu^{\frac{1}{\rho}}\left(1-\lambda^{\frac{1}{\theta}}\right)\ln\mu}{\theta^2\left(\mu^{\frac{1}{\rho}}-\lambda^{\frac{1}{\theta}}\mu^{\frac{1}{\theta}}\right)} > 0,\\ \frac{\partial \kappa}{\partial \rho} &= -\frac{100\left(1-\lambda^{\frac{1}{\theta}}\right)\mu^{\frac{1}{\theta}+\frac{1}{\rho}}\ln\mu}{\rho^2\left(\mu^{\frac{1}{\rho}}-\lambda^{\frac{1}{\theta}}\mu^{\frac{1}{\theta}}\right)^2} < 0,\end{aligned}$$

where the claim in part (c) of the proposition follow from noting that ρ and σ are positively correlated.

F Proof of proposition 3

F.1 Part (a): Lowering iceberg trade costs in the presence of tariffs

Rearranging equation (15), we obtain

$$\frac{\partial W}{\partial \lambda} = \frac{1}{\varepsilon}\frac{W}{\lambda}\left(1-\zeta\frac{\lambda(t-1)}{\lambda(t-1)+1}\right) < 0. \tag{23}$$

$$\begin{aligned}
\frac{\partial^2 W}{\partial \lambda^2} &= \frac{1}{\varepsilon}\frac{\frac{\partial W}{\partial \lambda}\lambda - W}{\lambda^2}\left(1-\zeta\frac{\lambda(t-1)}{\lambda(t-1)+1}\right) - \frac{\zeta(t-1)}{\varepsilon}\frac{W}{\lambda}\frac{\lambda(t-1)+1-\lambda(t-1)}{[\lambda(t-1)+1]^2} \\
&= \frac{W}{\varepsilon\lambda^2}\left(\frac{1}{\varepsilon}\left(1-\frac{\zeta\lambda(t-1)}{\lambda(t-1)+1}\right)^2 - 1 + \frac{\zeta\lambda(t-1)}{\lambda(t-1)+1} - \zeta\frac{\lambda(t-1)}{[\lambda(t-1)+1]^2}\right) \\
&= \frac{W}{\varepsilon\lambda^2}\left(\frac{1}{\varepsilon}\left(1-\frac{\zeta\lambda(t-1)}{\lambda(t-1)+1}\right)^2 - 1 + \zeta\frac{\lambda^2(t-1)^2}{[\lambda(t-1)+1]^2}\right) > 0,
\end{aligned}$$

where the inequality follows from $\varepsilon, \zeta < 0$.

F.2 Part (b). Lowering tariffs

Collecting terms in equation (16), we obtain

$$d\ln W = \frac{1-\zeta}{\varepsilon}\frac{\lambda(t-1)}{\lambda(t-1)+1}d\ln\lambda,$$

which implies

$$\frac{\partial W}{\partial \lambda} = \frac{1-\zeta}{\varepsilon}\frac{W(t-1)}{\lambda(t-1)+1}.$$

Then,

$$\begin{aligned}
\frac{\partial^2 W}{\partial \lambda^2} &= \frac{1-\zeta}{\varepsilon}\frac{\left[\frac{\partial W}{\partial \lambda}(t-1) + W\frac{\partial t}{\partial \lambda}\right][\lambda(t-1)+1] - W(t-1)\left[t-1+\lambda\frac{\partial t}{\partial \lambda}\right]}{[\lambda(t-1)+1]^2} \\
&= \frac{1-\zeta}{\varepsilon}W\frac{\frac{1-\zeta-\varepsilon}{\varepsilon}(t-1)^2 + \frac{\partial t}{\partial \lambda}}{[\lambda(t-1)+1]^2}.
\end{aligned}$$

Concavity requires

$$\frac{1-\zeta-\varepsilon}{\varepsilon}(t-1)^2 + \frac{\partial t}{\partial \lambda} > 0 \Leftrightarrow \frac{\varepsilon}{\zeta(1-\zeta-\varepsilon)} - \frac{(t-1)^2}{t}\lambda(1-\lambda) > 0,$$

where the second line follows from $d\ln\lambda = -(1-\lambda)\zeta d\ln t$.

Recall that gravity implies that $\lambda = \left(1+\xi t^{\zeta}\right)^{-1}$, where $\xi < 1$ is a constant term that collects non-tariff trade barriers. Then, the inequality can be rewritten as

$$\frac{\varepsilon}{\zeta\,(1-\zeta-\varepsilon)} > \frac{(t-1)^2}{\xi^{-1}t^{1-\zeta}\,(1+\xi t^{\zeta})^2} = \frac{(t-1)^2}{\xi t^{\zeta+1}+\xi^{-1}t^{1-\zeta}+2t}.$$

Note that an upper bound for the expression on the right hand side is

$$f\,[t] \equiv \frac{(t-1)^2}{\xi^{-1}t^{1-\zeta}},$$

with $f\,[1]=0$, $\lim_{t\to\infty} f\,[t]=0$ for $\zeta<1$, and

$$\frac{\partial f\,[t]}{\partial t} = \xi\,(t-1)\,t^{\zeta-1}\left(1+\zeta+(1-\zeta)\,t^{-1}\right).$$

The function $f\,[t]$ reaches its maxima at $t=1$ and

$$1+\zeta+(1-\zeta)\,t^{-1}=0 \Leftrightarrow t=\frac{1-\zeta}{-\zeta-1}$$

with

$$f\left[\frac{1-\zeta}{-\zeta-1}\right] = \xi\left(\frac{2}{-\zeta-1}\right)^2\left(\frac{1-\zeta}{-\zeta-1}\right)^{\zeta-1} < \left(\frac{2}{-\zeta-1}\right)^2\left(\frac{1-\zeta}{-\zeta-1}\right)^{\zeta-1},$$

where the inequality follows from $\xi<1$. Then, a sufficient condition for concavity is

$$\frac{\varepsilon}{\zeta\,(1-\zeta-\varepsilon)} > \left(\frac{2}{-\zeta-1}\right)^2\left(\frac{1-\zeta}{-\zeta-1}\right)^{\zeta-1}.$$

Eaton-Kortum. With $\gamma=-\varepsilon=-\zeta$, a sufficient condition for concavity is

$$\frac{1}{1+2\gamma} > \left(\frac{2}{\gamma-1}\right)^2\left(\frac{1+\gamma}{\gamma-1}\right)^{-\gamma-1},$$

which holds under regularity condition that guarantees finite variance of the sales distribution ($\gamma>2$).

Melitz. With $\varepsilon=-\theta$ and $\zeta=1-\theta/\rho$, a sufficient condition for concavity is

$$\left(\frac{\theta}{\theta-2\rho}\right)^{-\frac{\theta}{\rho}}\left(\frac{2}{\theta-2\rho}\right)^2(1+\rho)\,(\theta-\rho)<1. \tag{24}$$

The regularity condition that guarantees finite variance of the sales distribution is $\theta>2$. Another regularity condition postulates $\theta>\sigma-1=\rho/(1-\rho)$. A plot in the $(\theta,\rho)-$space shows that the inequality (24) holds for all feasible combinations of θ and ρ.