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Distorted Trade Barriers

Matthew T Cole, University College Dublin

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Distorted Trade Barriers*

Matthew T. Cole†
(University College Dublin)

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Abstract

Since firm heterogeneity has been introduced into international trade models, the importance of firm entry and exit (the extensive margin) has been highlighted. In fact, Chaney (2008) illustrates how accounting for this extensive margin and heterogenous firms alters the standard gravity equation; thereby reversing the previously predicted effect the elasticity of substitution has on the elasticity of trade flows. Furthermore, Cole (forthcoming) points out that *ad valorem* tariffs affect the extensive margin quite differently than the commonly used iceberg transport cost. In this paper, I show that the elasticity of trade flows with respect to tariffs is more elastic than that of iceberg transport costs. Thus, elasticity estimates derived from variables such as distance may underestimate the effect caused by a change in tariffs.

JEL classification: F12; F13; F17

Keywords: Intra-industry Trade; Gravity; Firm heterogeneity; Monopolistic competition

*I would like to thank Thomas Chaney for helpful comments. All remaining errors are my own.

†Corresponding author: School of Economics, University College Dublin, Newman Building (Room G215), Belfield, Dublin 4 Ireland. Email: matthew.cole@ucd.ie

1 Introduction

It is quite common in the literature to use iceberg transport costs (shipping more than one unit of output for one unit to arrive as a portion "melts" away) to represent variable trade barriers; both tariffs and shipping costs alike. For many models, this equivalence is a completely reasonable assumption. For instance, in models of perfect competition, iceberg transport costs and *ad valorem* tariffs are completely equivalent. However, despite the market price being identical under both types of trade barrier in models with monopolistic competition, the *level* of firm profit is not; and the level of profit determines firm entry and exit – the extensive margin.[1] Since monopolistic competition has been the workhorse model for international trade over the past 30 years, it is important to investigate the potential discrepancies between iceberg transport costs and *ad valorem* tariffs.

Since firm heterogeneity has been introduced into international trade models, the importance of the extensive margin has been highlighted. In fact, Chaney (2008) illustrates how accounting for this extensive margin and heterogenous firms alters the standard gravity equation; thereby reversing the previously predicted effect the elasticity of substitution has on the elasticity of trade flows. Specifically, Krugman (1980) predicts that a higher elasticity of substitution between goods magnifies the impact of trade barriers on trade flows, where Chaney (2008) shows that the effect on trade flows is actually dampened by higher levels of elasticity of substitution. The reasoning behind this reversal is driven by how the elasticity of substitution affects both the intensive and extensive margins. That is, the intensive margin is more sensitive but the extensive margin is less sensitive with a higher level of elasticity of substitution. Furthermore, with respect to iceberg transport costs, Chaney finds that the effect on the intensive and extensive margins exactly cancel out. It is this point in which I provide clarification. I utilize the Chaney framework and show that elasticity of trade flows with respect to an *ad valorem* tariff is not a constant but is decreasing in the elasticity of

[1] The different effect on firm profit is shown explicitly in Cole (forthcoming), which has fixed cost heterogeneity with quasi-linear utility and analyzes how iceberg transport costs and *ad valorem* tariffs affect the mass of varieties and welfare differently.

substitution, and that it is always greater than the elasticity of trade flows with respect to iceberg transport costs.[2] Thus, elasticity estimates derived from variables such as distance may underestimate the effect caused by a change in tariffs. So, if a policy maker were intending to maximize tariff revenue or to follow the welfare by adhering to the longstanding rule of setting the tariff equal to the inverse of the elasticity of export supply, she would set the tariff too high.

The rest of the paper proceeds as follows. Section 2 quickly sets up the model. Section 3 introduces trade and finds the elasticities of trade flows with respect to both trade barriers. Section 4 concludes.

2 Setup

I follow Chaney (2008) very closely, maintaining notation and setup, with two main exceptions. First, I additionally allow for an *ad valorem* tariff, s_{ij}^h, on goods shipped from country i to country j in sector h where $t_{ij}^h = 1 + s_{ij}^h > 1$. Secondly, I allow for the government to contribute a portion of its tariff revenue to a global mutual fund that consists of firm profits and government bonds, all other tariff revenue is thrown away. This last assumption is helpful for two reasons: One, it provides a reasonable point of comparison between the two trade barriers by restricting consumer income to be identical; and two, it keeps the model tractable.[3]

There are N potentially asymmetric countries that produce goods using only labor. Country n has a population of L_n. Consumers in each country maximize utility derived from the consumption of goods from $H+1$ sectors. Sector 0 provides a single freely traded homogenous good that pins down the wage in country n, w_n.[4] The other H sectors are made of a

[2] It will be shown that the elasticity of trade flows with respect to an *ad valorem* tariff is more elastic as long the elasticity of substitution is strictly greater than one, which is the standard assumption in the literature.

[3] It is inherent to the iceberg transport cost assumption that output (and income) is lost to the economy whereas tariffs create revenue for the government. Of course, implicit in this bond assumption is that governments are keeping a budget in line with this policy.

[4] I assume that every country produces a positive amount of q_0.

continuum of differentiated goods. If a consumer consumes q_o units of good 0, and $q_h(\omega)$ units of each variety ω of good h, for all varieties in the set Ω_h (determined in equilibrium), she gets a utility U,

$$U \equiv q_0^{\mu_0} \prod_{h=1}^{H} \left(\int_{\Omega_h} q_h(\omega)^{(\sigma_h - 1)/\sigma_h} d\omega \right)^{[\sigma_h/(\sigma_h - 1)]}, \tag{1}$$

where $\mu_0 + \sum_{h=1}^{H} \mu_h = 1$, and where $\sigma_h > 1$ is the elasticity of substitution between two varieties of good h.

2.1 Trade Barriers and Technology

There are three types of trade barriers, two variable (tariffs, t_{ij}^h, and iceberg transport costs, τ_{ij}^h) and a fixed cost (f_{ij}^h). Each firm in sector h draws a random unit labor productivity φ from a Pareto distribution with shape parameter γ_h.[5] Following Chaney (2008), I assume the total mass of potential entrants in each sector is proportional to $w_j L_j$. The cost of producing q units of a good and selling them in country j for a firm with productivity φ is

$$c_{ij}^h(p, q) = (t_{ij}^h - 1)pq + \tau_{ij}^h q + \frac{w_i}{\varphi} q + f_{ij}^h. \tag{2}$$

The price is the usual constant markup,

$$p_{ij}^h(\varphi) = \frac{\sigma_h}{(\sigma_h - 1)} \frac{t_{ij}^h \tau_{ij}^h w_i}{\varphi}$$

Note that the tariff and transport cost have the same affect on the price paid by consumers, however the actual profit level will be lower under an identical tariff which will have an effect on both the intensive and extensive margin.

[5] Productivity is distributed over $[1, +\infty)$ according to $P(\tilde{\varphi}_h < \varphi) = G_h(\varphi) = 1 - \varphi^{-\gamma_h}$, with $\gamma_h > \sigma_h - 1$.

2.2 Demand for Differentiated Goods

The total income spent by workers in country j, Y_j, is the sum of their labor income ($w_j L_j$) and of the dividends they get from their portfolio ($w_j L_j \pi$), where π is the dividend per share of the global mutual fund which consists of aggregated firm profits and government bonds. Fresh off the boat (pre-tariff) exports from country i to country j in sector h, by a firm with a labor productivity φ, are

$$x_{ij}^h(\varphi) = \frac{p_{ij}^h(\varphi) q_{ij}^h(\varphi)}{t_{ij}^h} = \frac{\mu_h Y_j}{t_{ij}^h} \left(\frac{p_{ij}^h(\varphi)}{P_j^h} \right)^{1-\sigma_h} \tag{3}$$

where P_j^h is the ideal price index for good h in country j. If only those firms above the productivity threshold $\bar{\varphi}_{kj}^h$ in country k and sector h export to country j, the ideal price index for good h in country j, P_j, and dividends per share, π, are defined as

$$P_j^h = \left(\sum_{k=1}^{N} w_k L_k \int_{\bar{\varphi}_{kj}^h}^{\infty} \left(\frac{\sigma_h}{(\sigma_h - 1)} \frac{w_k t_{kj}^h}{\varphi} \right)^{1-\sigma_h} dG_h(\varphi) \right)^{1/(1-\sigma_h)} \tag{4}$$

$$\pi = \frac{\sum_{h=1}^{H} \sum_{k,l=1}^{N} w_k L_k \left(\int_{\bar{\varphi}_{kl}^h}^{\infty} \pi_{kl}^h(\varphi) + b_{kl}^h(\varphi) dG(\varphi) \right)}{\sum_{n=1}^{N} w_n L_n} \tag{5}$$

where

$$\pi_{kl}^h(\varphi) = \left(\frac{1}{(\sigma_h - 1)} \right) \frac{\tau_{kl}^h w_k}{\varphi} q_{kl}^h(\varphi) - f_{kl}^h$$

are the net profits that firm with productivity φ in country k and sector h earns from exporting to country l, and

$$b_{kl}^h = \frac{(t_{kl} - 1) p_{kl}^h(\varphi) q_{kl}^h(\varphi)}{t_{kl} \sigma_h} = \left(\frac{(t_{kl} - 1)}{\sigma_h - 1} \right) \frac{\tau_{kl}^h w_k}{\varphi} q_{kl}^h(\varphi)$$

is the portion of tariff revenue contributed to the global mutual fund.

3 Trade with Heterogeneous Firms

In this section, I characterize the equilibrium with trade. Due to the independence of sectors, I only consider sector h and drop the h superscript.

3.1 Equilibrium with trade

The profits firm φ earns when exporting from country i to j are

$$\pi_{ij} = \frac{\mu Y_j t_{ij}^{-\sigma}}{\sigma} \left[\frac{\sigma}{(\sigma-1)} \frac{w_i \tau_{ij}}{\varphi P_j} \right]^{1-\sigma} - f_{ij}.$$

Define the threshold $\bar{\varphi}_{ij}$ from $\pi_{ij}(\bar{\varphi}_{ij}) = 0$ as the productivity of the least productive firm in country i able to export to country j:

$$\bar{\varphi}_{ij} = \lambda_1 \left(\frac{f_{ij} t_{ij}^{\sigma}}{Y_j} \right)^{\frac{1}{(\sigma-1)}} \frac{w_i \tau_{ij}}{P_j} \tag{6}$$

where $\lambda_1 = \left(\frac{\sigma}{\sigma-1}\right)\left(\frac{\sigma}{\mu}\right)^{1/(\sigma-1)}$ is a constant.

Recalling that $Y_k = w_k L_k (1+\pi)$ so $w_k L_k = \frac{Y_k}{(1+\pi)}$, the price index can be written as

$$P_j = \lambda_2 Y_j^{\frac{(\sigma-1)-\gamma}{\gamma(\sigma-1)}} \theta_j \tag{7}$$

where

$$\begin{aligned}
\lambda_2^{\gamma} &= \left(\frac{\gamma - (\sigma-1)}{\gamma} \right) \left(\frac{\sigma}{\mu} \right)^{\frac{\gamma-(\sigma-1)}{(\sigma-1)}} \left(\frac{\sigma}{(\sigma-1)} \right)^{\gamma} \left(\frac{1+\pi}{Y} \right) \\
\theta_j^{-\gamma} &= \sum_{k=1}^{N} \left(\frac{Y_k}{Y} \right) (w_k \tau_{ij})^{-\gamma} t_{kj}^{1+\frac{\sigma\gamma}{1-\sigma}} f_{kj}^{1+\frac{\gamma}{1-\sigma}}.
\end{aligned}$$

The term θ_j is a measure of country j's remoteness from the rest of the world such that τ_{ij} represents physical distance and t_{ij} represents its remoteness as a result of unilateral trade policy.

Using the general equilibrium price index, (7), I can solve for firm level exports, the productivity thresholds and total world profits:

$$x_{ij}(\varphi) = \begin{cases} \lambda_3 \left(\frac{Y_j}{Y}\right)^{\frac{(\sigma-1)}{\gamma}} t_{ij}^{-\sigma} \left(\frac{\theta_j}{w_i \tau_{ij}}\right)^{\sigma-1} \varphi^{\sigma-1}, \text{ if } \varphi \geq \bar{\varphi}_{ij} \\ 0 \text{ otherwise,} \end{cases} \tag{9}$$

$$\bar{\varphi}_{ij} = \lambda_4 \left(\frac{Y}{Y_j}\right)^{\frac{1}{\gamma}} \left(\frac{w_i \tau_{ij}}{\theta_j}\right) \left(f_{ij} t_{ij}^{\sigma}\right)^{\frac{1}{(\sigma-1)}}$$

$$Y_i = (1+\lambda_5) w_i L_i$$

$$\pi = \lambda_5$$

where λ_3, λ_4, and λ_5 are constants.[6] It is important to note how tariffs and transport costs enter into the equilibrium firm level of exports and productivity thresholds. These differences translate into the following gravity equation: Total (f.o.b.) X_{ij}^h in sector h from country i to country j are given by

$$X_{ij}^h = \mu_h \left(\frac{Y_i Y_j}{Y}\right) \left(\frac{w_i \tau_{ij}^h t_{ij}^{h\,\frac{\sigma_h}{\sigma_h - 1}}}{\theta_j}\right)^{-\gamma_h} f_{ij}^{-\left[\frac{\gamma_h}{(\sigma_h - 1)} - 1\right]}. \tag{10}$$

Exports are a function of country size (Y_i and Y_j), workers' productivity (w_i), the bilateral trade cost, variable (t_{ij}^h, τ_{ij}^h) and fixed (f_{ij}^h), and the measure of j's remoteness from the rest of the world (θ_j^h). Though it appears that tariffs and iceberg transport costs enter the gravity equation differently, recall that the remoteness measure is affected differently by each trade barrier and more analysis is necessary.

[6]

$$\begin{aligned} \lambda_3 &= \sigma \lambda_4^{1-\sigma} \\ \lambda_4 &= \left[\left(\frac{\sigma}{\mu}\right)\left(\frac{\gamma}{\gamma - (\sigma-1)}\right)\frac{1}{(1+\lambda_5)}\right]^{\frac{1}{\gamma}} \\ \lambda_5 &= \frac{\sum_{h=1}^{H} \left(\frac{\sigma_h - 1}{\gamma_h}\right) \frac{\mu_h}{\sigma_h}}{1 - \sum_{h=1}^{H} \left(\frac{\sigma_h - 1}{\gamma_h}\right) \frac{\mu_h}{\sigma_h}} \end{aligned}$$

As mentioned earlier, all else equal, the imposition of a tariff results in lower firm profits then the imposition of an identical iceberg transport costs (see Cole (forthcoming) for a proof). Furthermore, this simple difference in only the level of firm profits (recalling that the price consumers pay is identical under both trade barriers) translates into different trade flow elasticities in both the extensive *and* intensive margin. The corresponding elasticities are as follows:[7]

$$\text{Tariff:} \quad \rightarrow \vartheta \equiv -\frac{d\ln X_{ij}}{d\ln t_{ij}} = \underbrace{\sigma}_{\text{Intensive}} + \underbrace{\frac{\sigma\gamma}{\sigma-1} - \sigma}_{\text{Extensive}} = \frac{\sigma\gamma}{\sigma-1}, \tag{11}$$

$$\text{Iceberg:} \quad \rightarrow \zeta \equiv -\frac{d\ln X_{ij}}{d\ln \tau_{ij}} = \underbrace{(\sigma-1)}_{\text{Intensive}} + \underbrace{[\gamma-(\sigma-1)]}_{\text{Extensive}} = \gamma. \tag{12}$$

It is straightforward to see by comparing equation (11) with (12), that trade flows are more elastic with respect to changes in tariffs then transport costs,

$$\vartheta - \zeta = \frac{\gamma}{\sigma-1}.$$

What is interesting is that not only the overall trade flow is more elastic with respect to a tariff, but each margin (the intensive and extensive) is more elastic as well. At first glance, this may seem odd since the price paid by consumers is identical under both trade barriers. However, since profits are lower under a tariff, there are less firms in equilibrium. As such, each firm sells more under a tariff despite making lower profit. Furthermore, note that this difference between trade elasticities depends on the elasticity of substitution. This is because

[7]Note the claim by Chaney (2008) that the elasticity of trade flows is decreasing in the elasticity of substitution is not only maintained by using tariffs, but is strengthened by it:

$$\frac{d\vartheta}{d\sigma} = \frac{-\gamma}{(\sigma-1)^2} < 0.$$

for highly competitive industries where a firm's markup is quite low, the ability for a firm to recoup some of its transport costs is also lower. Additionally, the shape parameter of the firms' productivity distribution plays an important role. When a sector has a high γ, the smaller, less productive firms are producing relatively more of the sector's output and since changes in tariffs have a greater impact on whether these firms are producing or not, it will then also have a greater impact on the industry's aggregate trade flow. Therefore, if one wishes to use estimates of trade flow elasticities derived from data on distance, for instance, in order to assess the impact of tariff policy, the theory suggests that this estimate will underestimate the effect. In particular, this is the case for industries that are not very competitive (low σ) and are more homogeneous in productivity (high γ).

4 Conclusion

It is common in the recent trade literature to simply assume iceberg transport costs as a general proxy for many types of trade restrictions (in particular *ad valorem* tariffs). When perfect competition is assumed the two trade barriers are analogous. However, in the often used model of monopolistic competition, this is no longer the case. By using the Chaney (2008) framework, I illustrate that the trade flows are more elastic in response to changes in tariffs than iceberg transport costs. Since it is quite common to use distance to represent trade restrictions in gravity equations, it is important to understand this difference between tariffs and transport costs when anticipating the affects of tariff policy.

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A Mathematical Appendix

A.1 Deriving the Gravity Equation

Aggregate Exports in sector h from country i to country j is

$$X_{ij}^h = w_i L_i \int_{\bar{\varphi}_{ij}}^{\infty} x_{ij}^h(\varphi) dG(\varphi).$$

Using the specific assumption about the distribution G, this becomes

$$X_{ij}^h = w_i L_i \int_{\bar{\varphi}_{ij}}^{\infty} \lambda_3^h \left(\frac{Y_j}{Y}\right)^{\frac{(\sigma_h-1)}{\gamma_h}} (t_{ij}^h)^{-\sigma_h} \left(\frac{\theta_j^h}{w_i \tau_{ij}^h}\right)^{\sigma_h-1} \varphi^{\sigma_h-1} \frac{\varphi^{-\gamma_h-1}}{\gamma_h} d\varphi.$$

Solving this integral yields:

$$\begin{aligned}
X_{ij}^h &= \left(\frac{Y_j}{Y}\right)^{\frac{(\sigma_h-1)}{\gamma_h}} \left(\frac{\theta_j}{w_i \tau_{ij}^h}\right)^{\sigma_h-1} \frac{w_i L_i \lambda_3^h t_{ij}^{-\sigma_h} \gamma_h}{\gamma_h - (\sigma_h - 1)} \left[\lambda_4^h \left(\frac{Y}{Y_j}\right)^{\frac{1}{\gamma_h}} \left(\frac{w_i \tau_{ij}^h}{\theta_j}\right) \left(f_{ij} t_{ij}^{\sigma_h}\right)^{\frac{1}{(\sigma_h-1)}}\right]^{(\sigma_h-1)-\gamma_h} \\
&= w_i L_i \lambda_3^h \left(\frac{Y_j}{Y}\right) t_{ij}^{\frac{-\sigma_h \gamma_h}{\sigma_h - 1}} \left(\frac{\theta_j}{w_i \tau_{ij}^h}\right)^{\gamma_h} \frac{\gamma_h}{\gamma_h - (\sigma_h - 1)} \left[\lambda_4^h \left(f_{ij}\right)^{\frac{1}{(\sigma_h-1)}}\right]^{(\sigma_h-1)-\gamma_h} \\
&= \lambda_3^h (\lambda_4^h)^{(\sigma_h-1)-\gamma_h} \frac{\gamma_h}{\gamma_h - (\sigma_h - 1)} \left(\frac{w_i L_i Y_j}{Y}\right) t_{ij}^{\frac{-\sigma_h \gamma_h}{\sigma_h - 1}} \left(\frac{w_i \tau_{ij}^h}{\theta_j^h}\right)^{-\gamma_h} f_{ij}^{\frac{(\sigma_h-1)-\gamma_h}{(\sigma_h-1)}} \\
&= \sigma_h (\lambda_4^h)^{-\gamma_h} \frac{\gamma_h}{\gamma_h - (\sigma_h - 1)} \left(\frac{w_i L_i Y_j}{Y}\right) (t_{ij}^h)^{\frac{-\sigma_h \gamma_h}{\sigma_h - 1}} \left(\frac{w_i \tau_{ij}^h}{\theta_j^h}\right)^{-\gamma_h} f_{ij}^{\frac{(\sigma_h-1)-\gamma_h}{(\sigma_h-1)}} \\
&= \mu_h (1 + \lambda_5^h) \left(\frac{w_i L_i Y_j}{Y}\right) t_{ij}^{\frac{-\sigma_h \gamma_h}{\sigma_h - 1}} \left(\frac{w_i \tau_{ij}^h}{\theta_j}\right)^{-\gamma_h} f_{ij}^{\frac{(\sigma_h-1)-\gamma_h}{(\sigma_h-1)}} \\
&= \mu_h \left(\frac{Y_i Y_j}{Y}\right) t_{ij}^{\frac{-\sigma_h \gamma_h}{\sigma_h - 1}} \left(\frac{w_i \tau_{ij}^h}{\theta_j}\right)^{-\gamma_h} f_{ij}^{\frac{(\sigma_h-1)-\gamma_h}{(\sigma_h-1)}}
\end{aligned}$$

Therefore, total (f.o.b.) X_{ij}^h in sector h from country i to country j are given by

$$X_{ij}^h = \mu_h \left(\frac{Y_i Y_j}{Y}\right) \left(\frac{w_i \tau_{ij}^h t_{ij}^{h\,\frac{\sigma_h}{\sigma_h - 1}}}{\theta_j}\right)^{-\gamma_h} f_{ij}^{-\left[\frac{\gamma_h}{(\sigma_h-1)} - 1\right]}. \tag{A-1}$$

A.2 Deriving Elasticities

Totally differentiating (A-1) for a specific sector h and assuming $df_{ij} = 0$ yields the following elasticities:[8]

$$-\frac{d\ln X_{ij}}{d\ln t_{ij}} = \frac{-dX_{ij}/dt_{ij}}{X_{ij}/t_{ij}} = \underbrace{-\frac{t_{ij}}{X_{ij}}\left(w_i L_i \int_{\bar{\varphi}_{ij}}^{\infty} \frac{\partial x_{ij}(\varphi)}{\partial t_{ij}} dG(\varphi)\right)}_{\text{Intensive margin}} + \underbrace{\frac{t_{ij}}{X_{ij}}\left(w_i L_i x(\bar{\varphi}_{ij}) G'(\bar{\varphi}_{ij}) \frac{\partial \bar{\varphi}_{ij}}{\partial t_{ij}}\right)}_{\text{Extensive margin}}$$

$$-\frac{d\ln X_{ij}}{d\ln \tau_{ij}} = \frac{-dX_{ij}/d\tau_{ij}}{X_{ij}/\tau_{ij}} = \underbrace{-\frac{\tau_{ij}}{X_{ij}}\left(w_i L_i \int_{\bar{\varphi}_{ij}}^{\infty} \frac{\partial x_{ij}(\varphi)}{\partial \tau_{ij}} dG(\varphi)\right)}_{\text{Intensive margin}} + \underbrace{\frac{\tau_{ij}}{X_{ij}}\left(w_i L_i x(\bar{\varphi}_{ij}) G'(\bar{\varphi}_{ij}) \frac{\partial \bar{\varphi}_{ij}}{\partial \tau_{ij}}\right)}_{\text{Extensive margin}}$$

Using the definition of equilibrium individual exports from equation (9), and assuming that country i is small enough and/or remote enough, so that $\partial\theta_j/\partial t_{ij} \approx 0$ and $\partial\theta_j/\partial\tau_{ij} \approx 0$, I get

$$\frac{\partial x_{ij}(\varphi)}{\partial t_{ij}} = -\sigma \frac{x_{ij}(\varphi)}{\partial t_{ij}} \quad \text{and} \quad \frac{\partial x_{ij}(\varphi)}{\partial \tau_{ij}} = -(\sigma - 1)\frac{x_{ij}(\varphi)}{\partial \tau_{ij}}.$$

Integrating over all exporters, I get

$$\begin{aligned}
\textit{Elasticity of the intensive margin w.r.t. tariffs} &= -\frac{t_{ij}}{X_{ij}}\left(w_i L_i \int_{\bar{\varphi}_{ij}}^{\infty} \frac{\partial x_{ij}(\varphi)}{\partial t_{ij}} dG(\varphi)\right) \\
&= \sigma \frac{t_{ij}}{X_{ij}} \frac{w_i L_i \int_{\bar{\varphi}_{ij}}^{\infty} x_{ij}(\varphi) dG(\varphi)}{t_{ij}} \\
&= \sigma \frac{t_{ij}}{X_{ij}} \frac{X_{ij}}{t_{ij}} \\
&= \sigma.
\end{aligned}$$

Now, define $x_{ij} = \lambda_{ij}\varphi^{\sigma-1}$ and note that $G'(\varphi) = \varphi^{-\gamma-1}/\gamma$. Aggregate exports can be written in the following way

$$\begin{aligned}
X_{ij} &= w_i L_i \lambda_{ij} \int_{\bar{\varphi}_{ij}}^{\infty} \varphi^{\sigma-1} \gamma \varphi^{-\gamma-1} \\
&= \frac{\gamma}{\gamma - (\sigma - 1)} w_i L_i \lambda_{ij} \bar{\varphi}^{(\sigma-1)-\gamma} \\
&= \frac{1}{\gamma - (\sigma - 1)} w_i L_i x_{ij}(\bar{\varphi}) G'(\bar{\varphi}) \bar{\varphi}.
\end{aligned}$$

[8] The focus of this paper is to compare the effects of iceberg transport costs with that of an *ad valorem* tariff, thus analyzing changes in fixed costs would not add anything to the paper and would be exactly that found in Chaney (2008).

I therefore get the simple solution for the elasticity:

$$\begin{aligned}
\textit{Elasticity of the extensive margin w.r.t. tariffs} &= \frac{t_{ij}}{X_{ij}}\left(w_iL_ix_{ij}(\bar{\varphi})G'(\bar{\varphi})\frac{\partial\bar{\varphi}}{\partial t_{ij}}\right)\\
&= \frac{t_{ij}}{X_{ij}}\left(\frac{w_iL_ix_{ij}(\bar{\varphi})G'(\bar{\varphi})\bar{\varphi}}{t_{ij}}\frac{\sigma}{\sigma-1}\right)\\
&= (\gamma-(\sigma-1))\frac{t_{ij}}{X_{ij}}\left(\frac{X_{ij}}{t_{ij}}\frac{\sigma}{\sigma-1}\right)\\
&= \frac{\sigma\gamma}{\sigma-1}-\sigma.
\end{aligned}$$

Similarly for iceberg transport costs:

$$\begin{aligned}
\textit{Elasticity of the intensive margin w.r.t. iceberg costs} &= -\frac{\tau_{ij}}{X_{ij}}\left(w_iL_i\int_{\bar{\varphi}_{ij}}^{\infty}\frac{\partial x_{ij}(\varphi)}{\partial \tau_{ij}}dG(\varphi)\right)\\
&= (\sigma-1)\frac{\tau_{ij}}{X_{ij}}\frac{w_iL_i\int_{\bar{\varphi}_{ij}}^{\infty}x_{ij}(\varphi)dG(\varphi)}{\tau_{ij}}\\
&= (\sigma-1)\frac{\tau_{ij}}{X_{ij}}\frac{X_{ij}}{\tau_{ij}}\\
&= (\sigma-1).
\end{aligned}$$

$$\begin{aligned}
\textit{Elasticity of the extensive margin w.r.t. tariffs} &= \frac{\tau_{ij}}{X_{ij}}\left(w_iL_ix_{ij}(\bar{\varphi})G'(\bar{\varphi})\frac{\partial\bar{\varphi}}{\partial \tau_{ij}}\right)\\
&= \frac{\tau_{ij}}{X_{ij}}\left(\frac{w_iL_ix_{ij}(\bar{\varphi})G'(\bar{\varphi})\bar{\varphi}}{\tau_{ij}}\right)\\
&= (\gamma-(\sigma-1))\frac{\tau_{ij}}{X_{ij}}\left(\frac{X_{ij}}{\tau_{ij}}\right)\\
&= (\gamma-(\sigma-1)).
\end{aligned}$$

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