Transportation Cost Heterogeneity: New results for International Trade?

Fernando Letelier
Rutgers University

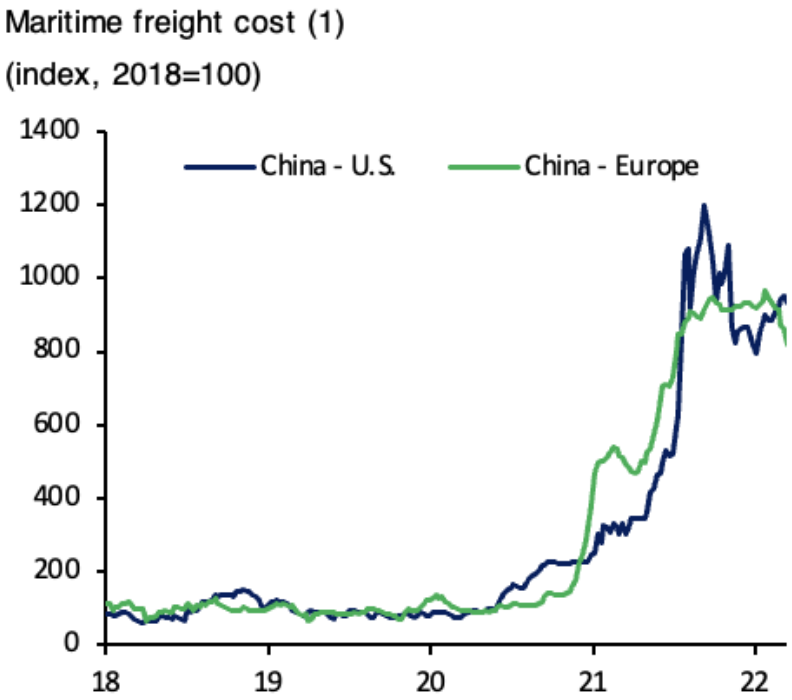
September 2025

Abstract

This paper introduces iceberg transportation costs to depend on firm productivity into a model with monopolistic competition, firm-level heterogeneity, and variable vs. constant markups, following the framework of Arkolakis et al. [2019]. Using micro-level trade data from Chile, I show that bigger firms face lower trade costs, challenging the standard assumption of uniform costs across firms. Incorporating this feature into an international trade model, I find that it strengthens the selection effect, raising the productivity threshold for exporting, and better matching empirical patterns. Applying the model to an increase of 25% in US tariffs, I show that while exports decline, the impact is less severe when trade costs vary with productivity.

1 Introduction

In recent decades, transportation costs and tariffs have decreased significantly. However, the COVID-19 pandemic led to a sharp increase in transportation costs, which rose tenfold. Figure 1 shows the cost of shipping a 40-foot container on routes from China to the U.S. and China to Europe. The data indicate that these costs remained stable from 2018 until the onset of the pandemic but surged to ten times their average level by the second half of 2021.

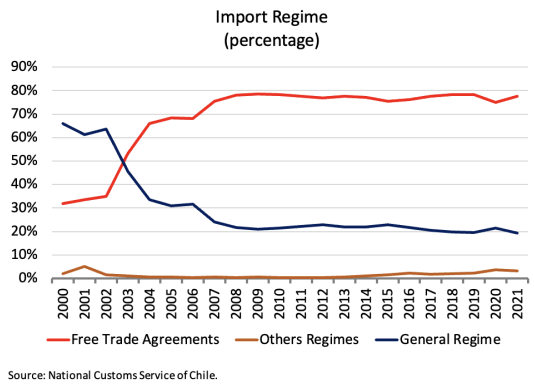


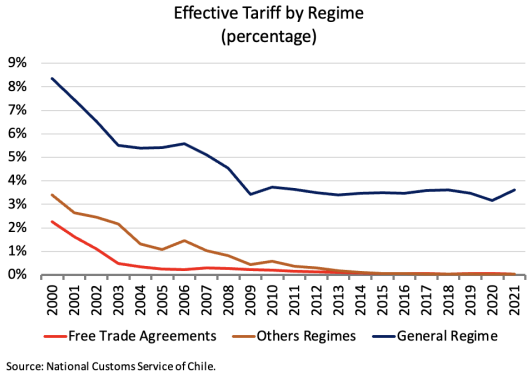
(1) Cost of transporting a 40-foot container in the respective routes.
Source: Bloomberg.

Hummels [2007] argues that transportation costs serve as a trade barrier at least as significant as tariffs, and often even greater. For instance, US import tariffs have declined from an average of 6.0% to 1.5% since 1950 (U.S. International Trade Commission), while the global average import tariff dropped from 8.6% to 3.2% between 1960 and 1995 (Clemens and Williamson [2004]). As tariffs become less restrictive, transportation costs play an increasingly important role in shaping international trade flows.

The case of Chile illustrates how tariffs have become less relevant in recent years. As a small open economy, Chile actively promotes free trade and has established numerous trade agreements with other countries and economic blocs. In fact, Chile has the most extensive network of Free Trade Agreements (FTAs) in the world, having negotiated 31 agreements covering 65 economies, which together account for 88% of global GDP.

In 2000, approximately 70% of Chilean imports entered under the General Regime, while the remaining 30% were covered by FTAs. However, two decades later, this distribution has shifted significantly, with 80% of imports now benefiting from FTAs and only 20% subject to the General Regime, as shown in Figure 2. Furthermore, Figure 3 illustrates how average tariffs have declined across both regimes. For instance, tariffs on imports under the General Regime fell by half between 2000 and 2021, decreasing from 8% to around 4%, while imports under FTAs saw their tariffs drop from 2% to 0%.





International trade models with heterogeneous firms, such as Melitz [2003], typically assume that transportation costs depend solely on the origin-destination pair. However, is this assumption realistic? Do transportation costs remain constant across firms with different characteristics?

The literature on transportation cost heterogeneity has explored various factors, including variable iceberg costs, endogenous trade costs and informational frictions.

Regarding variable iceberg costs, Alessandria et al. [2021] develop a heterogeneous firm general equilibrium model that incorporates time and risk into the export cost structure. In their framework, firms can gradually and stochastically reduce iceberg costs by investing in exporting. The model explains key empirical patterns, such as the tendency of new

exporters to start on a small scale, experience low survival rates, and take time to grow into large exporters.

In relation to endogenous trade costs, Brancaccio et al. [2020] find that maritime transport from Australia to China is 30% more expensive than in the reverse direction. This asymmetry arises because China primarily imports raw materials, limiting the opportunities for ships to secure return cargo. The authors derive equilibrium trade costs (transportation prices) and an expression for equilibrium bilateral trade flows, which resembles a gravity equation. Since ships operate in a forward-looking manner, trade costs are influenced not only by the origin and destination but also by factors such as regional location, freight values, match probabilities, and the attractiveness of neighboring regions.

Finally, another key factor is informational frictions. Allen [2014], using data on mobile phone access in the Philippines, finds that approximately half of the observed price dispersion between regions is attributable to informational frictions rather than transportation costs. This suggests that the transportation costs required to explain the observed price dispersion are only half as large as those estimated using a standard no-arbitrage equation, bringing the estimates more in line with observed freight costs.

To analyze the heterogeneity of transportation costs, I use import data from 2010 to 2022, provided by the National Customs Service of Chile. Focusing specifically on imports from China, I examine shipments where the Port of Origin is Shanghai and the Port of Destination is San Antonio. I control for variables such as the number of years the firm has been importing along the same route, the number of years it has been importing from any country, and the weight of the imports. Applying fixed effects for year and product, I find that a 1% increase in total imports by the firm from all destinations (used as a proxy for firm size) leads to a reduction in transportation costs—measured as Freight/CIF—by between 0.4 and 0.7 percentage points. These results suggest significant heterogeneity in transportation costs across firms.

Then, I incorporate transportation costs that depend on firm productivity into a model with monopolistic competition, firm-level heterogeneity, and variable vs. constant markups, using the same framework that Arkolakis et al. [2019], to examine how these changes affect trade outcomes.

2 Data and Empirical Evidence

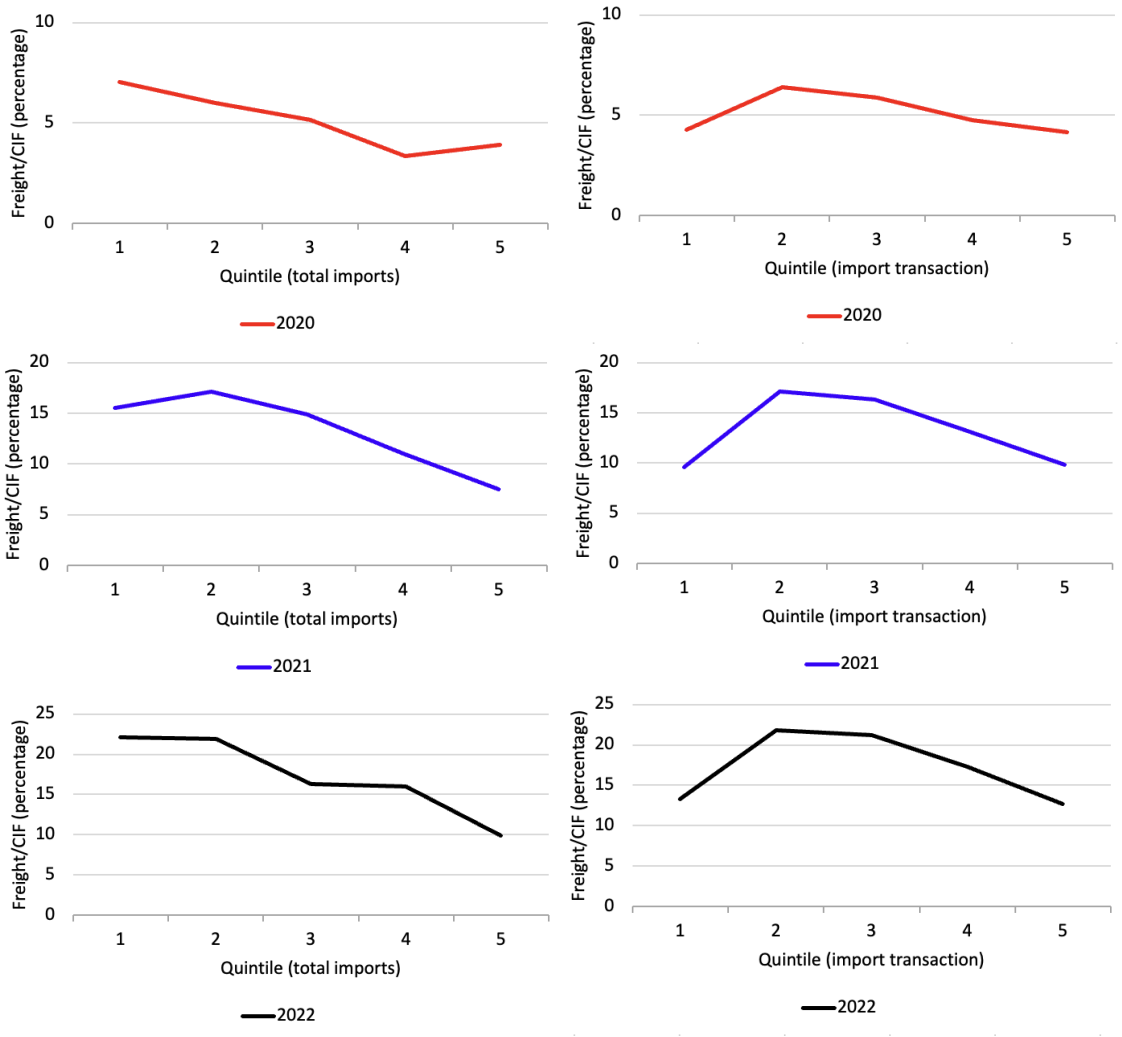
This section outlines the data used to estimate the effect of firm size on transportation costs and details the empirical strategy employed in the analysis.

2.1 Data

To study the heterogeneity of transportation costs, I analyze Chilean import data for the month of February from 2010 to 2022, provided by the National Customs Service of Chile. The dataset includes variables such as the Operation Number, Importing Company Number, Country of Origin, Country of Destination, Mode of Transport, Port of Shipment, Port of Landing, Freight Cost, Total Weight, CIF, and Product Code (HSC).

Focusing on Chilean imports from China, I analyze shipments where the Port of Origin is Shanghai and the Port of Destination is San Antonio, calculating transportation costs as Freight Cost/CIF. Figure 4 compares transportation costs by quintile for February 2020 (just before the COVID-19 pandemic), February 2021, and February 2022. The left column displays transportation costs by quintile of total firm imports (from all origins), serving as a proxy for firm size or productivity. According to the international trade literature, firms involved in international trade tend to be larger and more productive. The right column shows transportation costs by quintile of the import transaction value.

We can conclude that there is a negative relationship between firm size or productivity and transportation costs, meaning that larger and more productive firms face lower transportation costs. One might hypothesize that this could be related to the fixed costs of transportation—larger firms importing higher-value products should experience lower transportation costs due to the way transportation costs are measured. However, this is not the case. There is no observed relationship between the import value (transaction value) and transportation costs.



2.2 Empirical Strategy

To assess the effect of firm'size on transportation costs, I estimate the following regression:

$$y_{i,t} = \alpha + \beta TI_{i,t} + \gamma X_{i,t} + \mu_t + \eta_i + \epsilon_{i,t} \tag{1}$$

Where index i corresponds to the firm and t to the year. The dependent variable $y_{i,t}$ corresponds to the transportation cost, measured as the freight cost divided by the import value for firm i in year t. The independent variables are as follows: $TI_{i,t}$ which represents the total value of imports from all origins by firm i in year t. The vector of controls, denoted by $X_{i,t}$, includes the number of years the firm has been importing along the same route,

the number of years it has been importing from any country and the weight of the imports. And finally, μ_t represents year fixed effects and η_i represents firm fixed effects. $\epsilon_{i,t}$ is the unobservable error term.

3 Results

I estimated the OLS regression and applied fixed effects by year, as shown in Table 1. Table 2 shows the results for fixed effects of the importer firm, treating all imports along the same route by a firm as a single transaction. In Table 3, I included product fixed effects to account for the possibility that larger firms may import different types of products, which could contribute to the observed heterogeneity in transportation costs. Furthermore, in Table 3, I separated transactions into two categories: those with a value less than \$13,000 and those between \$13,000 and \$29,900. As discussed in the Data subsection, transaction value could explain some of the heterogeneity, particularly if freight costs have a significant fixed component and larger firms tend to import higher-value products.

Through these considerations and robust analysis, I found a significant effect: a 1% increase in total imports by the firm from all destinations, serving as a proxy for firm size, reduces transportation costs - measured as Freight / CIF - between 0.4 and 0.7 percentage points. These results highlight significant heterogeneity in transportation costs across firms and suggest the need to introduce an iceberg cost that depends on firm productivity in an international trade model with firm-level heterogeneity.

This relationship between firm size and productivity is supported by previous research, such as Bernard et al. [2003], which finds that, on average, more efficient suppliers have a greater cost advantage over their competitors, set higher markups, and exhibit higher measured productivity. In addition, more productive firms typically compete with more productive rivals, charge lower prices, and experience higher sales.

Table 1: Effect of Firm's size on Transport Cost

Freight Cost/CIF	(1) OLS	(2) Year Fixed Effects
Total Imports	-0.577***	-0.751***
	(0.0282)	(0.0276)
Experience (years importing all origins)	0.270***	-0.00936
	(0.0197)	(0.0192)
Experience (years importing same route)	-0.727***	0.182***
	(0.0230)	(0.0254)
Total weight	0.950***	0.964***
	(0.0350)	(0.0336)
Constant	8.850***	8.070***
	(0.566)	(0.528)
Observations	26,711	26,711
R-squared	0.138	0.329
Year FE		Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 2: Effect of Firm's size on Transport Cost

Freight Cost/CIF	(1) OLS	(2) Fixed Effects	(3) Fixed Effects
Total Imports	-1.009***	-0.810***	-0.747***
	(0.0768)	(0.200)	(0.189)
Experience (years importing all origins)	0.276***	0.972***	-0.0306
	(0.0349)	(0.143)	(0.340)
Experience (years importing same route)	-1.049***	-1.294***	-0.163
	(0.0646)	(0.211)	(0.203)
Total weight	1.089***	0.466***	0.783***
	(0.0861)	(0.167)	(0.154)
Constant	12.34***	11.95***	11.08***
	(0.802)	(2.419)	(2.200)
Observations	7,443	7,443	7,443
R-squared	0.059	0.049	0.252
Number of Firms		5,212	5,212
Firm FE		Yes	Yes
Year FE			Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3: Effect of Firm's size on Transport Cost

Freight Cost/CIF	(1) Fixed Effects	(2) Fixed Effects	(3) Fixed Effects
Total Imports	-0.699***	-0.414***	-0.765***
	(0.029)	(0.055)	(0.057)
Experience (years importing all origins)	0.033***	0.087***	0.073
	(0.016)	(0.037)	(0.031)
Experience (years importing same route)	0.140***	0.043	0.138
	(0.031)	(0.067)	(0.058)
Total weight	0.382***	0.237***	3.377***
	(0.035)	(0.087)	(0.158)
Constant	14.03***	14.18***	-14.217***
	(6.590)	(6.808)	(6.459)
Observations	18,610	5,203	5,309
R-squared	0.528	0.474	0.647
Product FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

*Second column imports lower than 13,000. *Third column imports higher than 13,000 and lower than 29,900.

4 Explanation of the fact: Better match or second-degree price discrimination?

The fact told us that larger import firms face lower transportation costs. But what is the explanation of this? Is it due to larger firms matching with more productive transportation firms or is it because transportation firms give lower prices to biggest import firms, due to the fact that bigger firms do more shipments trips?

I analyze this including in the regression the information of the relation with the transportation firm. The first column of Table 4 shows that the hypothesis of a better match is rejected because when I incorporated a fixed effect of the transportation firm, the effect of total import in the transportation cost practically does not change and continues to be significant. If the explanation of a better match would be correct, the effect of total imports should be non-significant because the cause of the lower transportation cost would be the relation with a more productive transportation firm, not the fact to be a bigger importer.

Column 2 of the same table gives the answer. I can see that the explanation for why larger firms face a lower transportation cost is related to the fact that larger firms make a higher number of import transactions with the same transportation firms. Supporting the hypothesis of second-degree price discrimination or nonlinear pricing. This occurs when prices differ depending on the number of units of the good bought, but not across consumers. That is, each consumer faces the same price schedule, but the schedule involves different prices for different amounts of the good purchased. Quantity discounts or premia are the obvious examples (Varian [1985]). So, in this case, the transportation firm cannot observe the buyer's willingness to pay or productivity. But it offers a menu of price-quantity bundles. Buyers choose the bundle that gives them the highest utility. Larger buyers (with higher demand or productivity) tend to choose bigger bundles with lower per-unit prices.

Table 4: Effect of Firm's size on Transport Cost

Freight Cost/CIF	(1) Fixed Effects	(2) Fixed Effects
Total Imports	-0.717***	
	(0.030)	
Experience (years importing all origins)	0.027*	-0.009
	(0.016)	(0.016)
Experience (years importing same route)	0.094***	0.067**
	(0.032)	(0.032)
Total weight	0.365***	0.176***
	(0.035)	(0.036)
Transactions (by transportation firm)		-0.831***
		(0.042)
Constant	15.034**	9.509
	(7.013)	(7.041)
Observations	18,610	18,610
R-squared	0.540	0.535
Product FE	Yes	Yes
Year FE	Yes	Yes
Trans. Firm FE	Yes	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

5 Model: ACDR with iceberg costs dependent on firm productivity

I incorporate transportation costs dependent on firm productivity into a model with monopolistic competition, firm-level heterogeneity, and variable vs. constant markups, following the framework of Arkolakis et al. [2019].

Consider a world economy consisting of $i = 1, ..., n$ countries, a single factor of production, labor, and a continuum of differentiated goods indexed by $\omega \in \Omega$. All individuals are perfectly mobile across the production of different goods but immobile across countries. Let L_i denote the population and w_i the wage in country i.

All consumers share the same preferences and income, y, which derives from their wages and, if applicable, the profits of firms in their country. If a consumer with income y faces a schedule of prices $p \equiv p(\omega)_{\omega \in \Omega}$, her Marshallian demand for any differentiated good ω is given by

$$q_\omega(p, y) = Q(p, y)D(p_\omega/P(p, y)) \tag{2}$$

where $D()$ is a strictly decreasing function and $Q(p, y)$ and $P(p, y)$ are two aggregate demand shifters, which firms will take as given in subsequent sections. Note that while $Q(p, y)$ affects only the level of demand, $P(p, y)$ influences both the level and elasticity of demand, which will have important implications for firm-level markups.

To complete the description of the demand system, I assume that $Q(p, y)$ and $P(p, y)$ are jointly determined as the solution of the following system of two equations,

$$\int_{\omega \in \Omega} [H(p_\omega/P)]^\beta [p_\omega Q D(p_\omega, P)]^{1-\beta} d\omega = y^{1-\beta}, \tag{3}$$

$$Q^{1-\beta} [\int_{\omega \in \Omega} p_\omega Q D(p_\omega, P) d\omega]^\beta = y^\beta, \tag{4}$$

with $\beta \in 0, 1$ and $H()$ strictly increasing and strictly concave.

Three key properties of the general demand system introduced above are worth highlighting. First, the own-price elasticity, $\partial lnD(p_\omega/P(p,y))/\partial ln(p_\omega)$, varies with prices, leading to variable markups under monopolistic competition. Second, the demand for good ω is influenced by other prices only through their effect on the aggregate demand shifters, $Q(p,y)$ and $P(p,y)$. Third, the demand parameter β determines whether preferences are homothetic. If $\beta = 1$, equations (2) and (3) imply that $P(p,y)$ is independent of y and that $Q(p,y)$ is proportional to y, indicating homothetic preferences. Conversely, if $\beta = 0$, preferences are non-homothetic unless $D()$ is isoelastic, i.e. utility functions are CES.

There exists a threshold a such that for all $x \geq a$, $D(x) = 0$. Without loss of generality, I normalize a to one for the remainder of our analysis, ensuring that the aggregate demand shifter $P(p,y)$ also corresponds to the choke price. In the absence of fixed costs associated with accessing domestic and foreign markets—which is the case I focus on—this assumption implies that the creation and elimination of "cut-off" goods have no first-order effects on welfare at the margin. Indeed, if consuming these goods provided any benefit, they would be demanded in strictly positive quantities.

For future derivations, it is convenient to write the demand function in a way that makes explicit the symmetry across goods as well as the way in which the aggregate demand shifters, $Q(p,y)$ and $P(p,y)$, affect the demand for all goods. Thus, I write $q_\omega(p,y) \equiv q(p_\omega, Q(p,y), P(p,y))$, with

$$q_\omega(p_\omega, Q, P) = QD(p_\omega/P). \tag{5}$$

Firms compete under monopolistic competition. Entry may be restricted or free. Under restricted entry, there is an exogenous measure of firms,N_i, with the right to produce in each country i. Under free entry, there is a large number of ex ante identical firms that have the option of hiring $F_i > 0$ units of labor to enter the industry. Firms then endogenously enter up to the point at which aggregate profits net of the fixed entry costs, $w_i F_i$, are zero. I let N_i denote the measure of firms in country i.

Upon entry, production of any differentiated good is subject to constant returns to scale. For a firm with productivity z in country i, the constant cost of delivering one unit of the variety associated with that firm to country j is given by $w_i \bar{z} \tau_{ij}/z^2$.

The key innovation of the new model lies in its treatment of iceberg transportation costs. In standard international trade models with firm heterogeneity, each firm from country i

that wishes to sell to destination j incurs an iceberg cost, expressed in labor units, $\tau_{ij} \geq 1$. This cost is typically assumed to be constant across firms, regardless of their productivity. Now, this iceberg cost depends on firm's productivity, $\tau_{ij}(z) \equiv \bar{z}\tau_{ij}/z \geq 1$. So, a firm with productivity lower than $\bar{z}$ faces higher transport cost than in model with constant iceberg cost and a firm with a productivity higher than $\bar{z}$, faces a lower iceberg cost. As mentioned earlier, there are no fixed costs of accessing domestic and foreign markets. Thus, the selection of firms across markets is driven entirely by the existence of a choke price, as in Melitz and Ottaviano [2008]

Throughout the analysis, I assume that good markets are perfectly segmented across countries and that parallel trade is prohibited so that firms charge the optimal monopoly price in each market. As in Melitz [2003], firm-level productivity z is the realization of a random variable drawn independently across firms from a distribution G_i. I assume that G_i is Pareto with the same shape parameter $\theta > 0$ around the world. For all $z \geq b_i, G_i(z) = 1 - (bi/z)^{\theta}$, with $\theta > 0$.

Now, consider the optimization problem of a firm producing good ω in country i and selling it in a certain destination j.

Under monopolistic competition with segmented good markets, the firm chooses its market-specific price p in order to maximize profits in each market,

$$\pi(c, Q, P) = \max_{p} (p - c)q(p, Q, P) \tag{6}$$

taking Q and P as given, The associated first-order condition is

$$(p - c)/p = -1/(\partial lnq(p, Q, P)/\partial lnp), \tag{7}$$

which states the monopoly markups are inversely related to the elasticity of demand.

I define $m \equiv p/c$ as the measure of firm-level markups. So, $m \equiv pz^2/w_i\bar{z}\tau_{ij}$ markups are more dependent on firm productivity, it means that more productive firms have higher markups because face lower marginal cost and face lower iceberg cost. Combining the previous expression with equation (5), I can express m as the implicit solution of

$$m = \epsilon_D(m/v)/(\epsilon_D(m/v) - 1), \tag{8}$$

where $\epsilon_D(x) \equiv -\partial lnD(x)/\partial lnx$ measures the elasticity of demand and $v \equiv P/c$, replacing

c, $v \equiv Pz^2/w_i\bar{z}\tau_{ij}$, can be thought of as a market-specific measure of the efficiency of the firm relative to other firms participating in that market, as summarized by P. Equation (8) implies that the aggregate demand shifter P is a sufficient statistic for all indirect effects that may lead a firm to change its price in a particular market. I assume that for any $v > 0$, there exists a unique $m \equiv \mu(v)$ that solves equation (8). Assuming that ϵ'_D is a sufficient, but not necessary condition for existence and uniqueness. For a firm with marginal cost c and relative efficiency v the price charged in any given market is given by $p(c, v) = c\mu(v)$. Given this pricing rule, the total sales faced by a firm with marginal cost c and relative efficiency v in a market with aggregate demand shifter Q and population L, are equal to

$$x(c, v, Q, L) \equiv LQC\mu(v)D(\mu(v)/v). \tag{9}$$

In turn, the profits of a firm with marginal cost c and relative efficiency v selling in a market with aggregate shifter Q and population L are given by

$$\pi(c, v, Q, L) \equiv ((\mu(v) - 1)/\mu(v))x(c, v, Q, L). \tag{10}$$

Let X_{ij} denote the total sales by firms from country i in country j. Only firms with marginal cost $c \leq P_j$ sell in country j. Thus there exists a productivity cut-off $z_{ij} \equiv (w_i\bar{z}\tau_{ij}/P_j)^{1/2}$ such that a firm from country i sells in country j if and only if its productivity $z \geq z^*_{ij}$. In the model without iceberg cost dependent in firm's productivity the productivity cut-off $z_{ij} \equiv (w_i\tau_{ij}/P_j)$. Like I know that $\bar{z}$ has to be higher than z^*_{ij}, in the new model the productivity cut-off is higher than in the old models. So, firms with productivity $z^{*New}_{ij} \geq z_{ij} \geq z^{*Old}_{ij}$ export in old models, but they don't do it in a model with iceberg cost heterogeneous. Because, these firms face higher marginal costs for produce the good, than most productives firms, but now higher iceberg cost for transport the good. So, in this model firms have to be more productive to be envolved in international trade.

Accordingly, I can express the bilateral trade flows between the two countries as

$$X_{ij} = N_i \int_{z_{ij}}^{\infty} x(w_i\bar{z}\tau_{ij}/z^2, z/z^*_{ij}, Q_j, L_j)dG_i(z). \tag{11}$$

Combining this expression with equation (9) and using my Pareto assumption, I get, after simplifications,

$$X_{ij} = \chi N_i b_i^{\theta}(w_i\bar{z}\tau_{ij})^{-\theta/2}L_jQ_j(P_j)^{(\theta+2)/2}, \tag{12}$$

where $\chi \equiv \theta\int_1^{\infty}(\mu(v)/v)D(\mu(v)/v)v^{-\theta-2}dv > 1$ is a constant that affects overall sales.

In the original ACDR model, without an iceberg cost dependent on firm productivity, equation (12) is equal to: $\mathrm{X}_{ij} = \chi N_i b_i^{\theta} (w_i \tau_{ij})^{-\theta} L_j Q_j (P_j)^{1+\theta}$,

where $\chi \equiv \theta \int_1^{\infty} (\mu(v)/v) D(\mu(v)/v) v^{-\theta-1} dv > 0$ is a constant that affects overall sales. So, we can see how the trade cost elasticity changes from $-\theta$ to $-\theta/2$, when the iceberg cost depends on the productivity of the firm. Therefore, an increase in the iceberg cost has a more negative impact on trade flows in the new model than in the original ACDR model.

Let Π_{ij} denote aggregate profits by firms from country i in country j gross of fixed entry costs. This is given by

$$\Pi_{ij} = N_i \int_{z_{ij}^*}^{\infty} \pi(w_i \bar{z} \tau_{ij}/z^2, z/z_{ij}^*, Q_j, L_j) dG_i(z). \tag{13}$$

Using equation (9) and (10), and again invoking the Pareto assumption, I get

$$\Pi_{ij} = \pi N_i b_i^{\theta} (w_i \bar{z} \tau_{ij})^{-\theta/2} L_j Q_j (P_j)^{(\theta+2)/2}, \tag{14}$$

where $\pi \equiv \theta \int_1^{\infty} (\mu(v) - 1) D(\mu(v)/v) v^{-\theta-3} dv > 0$ is a constant that affects overall profits.

For future reference, note that equations (12) and (14) imply that aggregate profits are a constant share of aggregate sales,

$$\Pi_{ij} = \zeta X_{ij} \tag{15}$$

where $\zeta \equiv (\pi/\chi) \in (0, 1)$. Finally, let $Y_j \equiv y_j L_j$ denote aggregate income country j. It is equal to the sum of wages and profits, which must add up to the total sales of firms from country j.

$$Y_j = \sum_i X_{ji} \tag{16}$$

In this model entry is free. And free entry requires that the sum of expected profits across all markets be equal to the entry costs, which can be expressed as:

$$N_i = \sum_j \Pi_{ij}/(w_i F_i) \tag{17}$$

This implies, in particular, that entry levels are invariant to changes in trade costs.

Labor market clearing and free entry, in turn, require that total sales across all markets be equal to the total wage bill:

$$w_i L_i = \sum_j X_{ij} \tag{18}$$

A trade equilibrium corresponds to price schedules, $(p_1, ..., p_n)$, measures of firms, $(N_1, ..., N_n)$, and wages, $(w_1, ..., w_n)$, such that (1) prices set in country j by firms with productivity z located in country i maximize their profits:

$$p_{ij}(z) = (w_i \bar{z} \tau_{ij}/z^2)\mu(Pz^2/w_i \bar{z} \tau_{ij}) \tag{19}$$

if $z \geq (w_i \bar{z} \tau_{ij}/P_j)^{(1/2)}$ and $p_{ij} \geq w_i \bar{z} \tau_{ij}/z^2$ otherwise; (2) measures of entrants are given by equation (17); and (3) wages are consistent with labor market clearing, equation (18), with aggregate demand shifters, Q_j and P_j, determined by equations (3) and (4), aggregate sales X_{ij} determined by equation (12), and aggregate income Y_j determined by equation (16). Note that under the previous equilibrium conditions, trade is necessarily balanced: since the Marshallian demand in must satisfy the budget constraint of the representative consumer, $y_j = \sum_i X_{ij}/L_j$, equation (16) immediately implies

$$\sum_i X_{ji} = \sum_i X_{ij} \tag{20}$$

6 New Model, New Results

In this section, I analyze how the results of the model change when incorporating an iceberg cost that depends on firm productivity. Starting from the calibrated economy of Arkolakis et al. [2019], I compare the outcomes of the standard model with those of the new model, where transportation costs vary with firm productivity.

I rely on numerical simulations, focusing on a world economy with two symmetric countries. I normalize country size to $L = 1$ and set the fixed entry cost to $F = 1$. In all simulations, I use the demand system estimated in Arkolakis et al. [2019], with parameter values $\alpha = 0$ and $\gamma = -0.221$ for the CES case and $\alpha = 1.5$ and $\gamma = -0.253$ for the generalized CES case. Trade costs and the parameters of the firm-level productivity distribution are calibrated to match the US imports-to-expenditure ratio and the trade elasticity. The values of all calibrated parameters are reported in Table 5.

Table 5: Calibration

Parameter	Value	Target/Choice Calibration
		Panel A: Demand
α (CES)	0	Arkolakis et al. [2019]
γ (CES)	-0.221	Arkolakis et al. [2019]
α (gen. CES)	1.5	Arkolakis et al. [2019]
γ (gen. CES)	-0.253	Arkolakis et al. [2019]
		Panel B: Pareto productivity distribution
θ	5	Trade Elasticity (Arkolakis et al. [2019])
τ	1.68	Imports/expenditure = 7% (OECD Input-Output Database, 2000)
$\bar{z}$ (CES)	0.75	Imports/expenditure = 7% (OECD Input-Output Database, 2000)
$\bar{z}$ (gen. CES)	0.55	Imports/expenditure = 7% (OECD Input-Output Database, 2000)

For the baseline calibration with a Pareto distribution, this implies a Pareto shape parameter of $\theta = 5$. In the standard model, the iceberg cost is set to 1.68, calibrated to match the 7% imports-to-total-expenditure ratio. To ensure comparability, the iceberg cost remains at 1.68 in the new model. However, the threshold productivity level $\bar{z}$ is calibrated separately for different utility specifications: in the generalized CES case, $\bar{z} = 0.55$, while in the CES case, $\bar{z} = 0.75$.

Tables 6 and 7 present the results of both models. The new model, incorporating the productivity-dependent iceberg cost, yields a fraction of exporting firms that aligns more closely with empirical observations. Specifically, in the generalized CES utility case, 3% of total firms export while maintaining an export share of 7% of total expenditure, whereas in the CES utility case, 2.4% of firms export. These results are consistent with the findings of Bernard et al. [2007], who report that among the 5.5 million firms operating in the United States in 2000, only 4% were exporters.

Table 6: Results: Old Model / New Model (CES)

Model	Old	New
FracExporters	0.075	0.024
ExportShare	0.070	0.069
p^*	5.568	5.551
z_d	0.217	0.218
z_x	0.365	0.460
N	0.156	0.159
MeanMarkupNonexporters	0.074	0.091
MeanMarkupExporters	0.186	0.214

Table 7: Results: Old Model / New Model (generalized CES)

Model	Old	New
FracExporters	0.075	0.030
ExportShare	0.070	0.070
p^*	5.443	5.427
z_d	0.184	0.184
z_x	0.309	0.370
N	0.167	0.170
MeanMarkupNonexporters	0.100	0.109
MeanMarkupExporters	0.215	0.176

Moreover, the results confirm that in both cases of the new model, the export cutoff productivity is higher than in the original model, as predicted by the theoretical framework. Since less productive exporting firms in the original model now face higher iceberg costs, they are driven out of international trade. Consequently, firms must be more productive to engage in exporting under the new model.

Another important conclusion from Tables 6 and 7 is the change in mean markups for both non-exporting and exporting firms. In both cases—under CES and generalized CES utility functions—the introduction of a productivity-dependent iceberg cost increases the mean markup for non-exporting firms. Specifically, in the CES case, the average markup rises from 7.4% to 9.1%, while in the generalized CES case, it increases from 10% to 10.9%. This occurs because, under the new model, the least productive firms that previously exported are now unable to do so. As a result, the average productivity of non-exporting firms increases, leading to higher markups.

For exporting firms, the effect differs depending on the utility function. In the CES case, the mean markup increases from 18.6% to 21.4%. This is because firms must be more productive to export, which reduces their marginal cost, while the CES assumption ensures that markups remain constant. However, in the generalized CES case, the impact of variable markups leads to a different outcome. Since the export cutoff productivity is higher in the new model, the relative productivity of each exporting firm—compared to the new higher cutoff—is lower. This means that each firm imposes a lower markup than in the original model. This effect outweighs the reduction in marginal cost, leading to a decrease in the average markup for exporters from 21.5% to 17.6% in the generalized CES case.

Figures 1 and 2 illustrate the distribution of sales—normalized by mean sales—across markets for French firms at the 5th, 25th, 50th, 75th, and 95th percentiles. As first documented by Eaton et al. [2004], the data reveal significant heterogeneity: compared to the mean exporter, firms at the 5th, 50th, and 95th percentiles sell less than 1/100th, around 1/10th, and three times as much, respectively.

The new model, which incorporates a transport cost that depends on firm productivity, better replicates the observed distribution of firm exports compared to the original model with a constant iceberg cost. The main improvement occurs among the smallest exporters. In the new model, these less productive firms face higher transport costs, which reduces their export sales relative to the original model. This adjustment aligns more closely with the empirical distribution observed in the data, improving the model's fit, particularly for the lower end of the distribution.

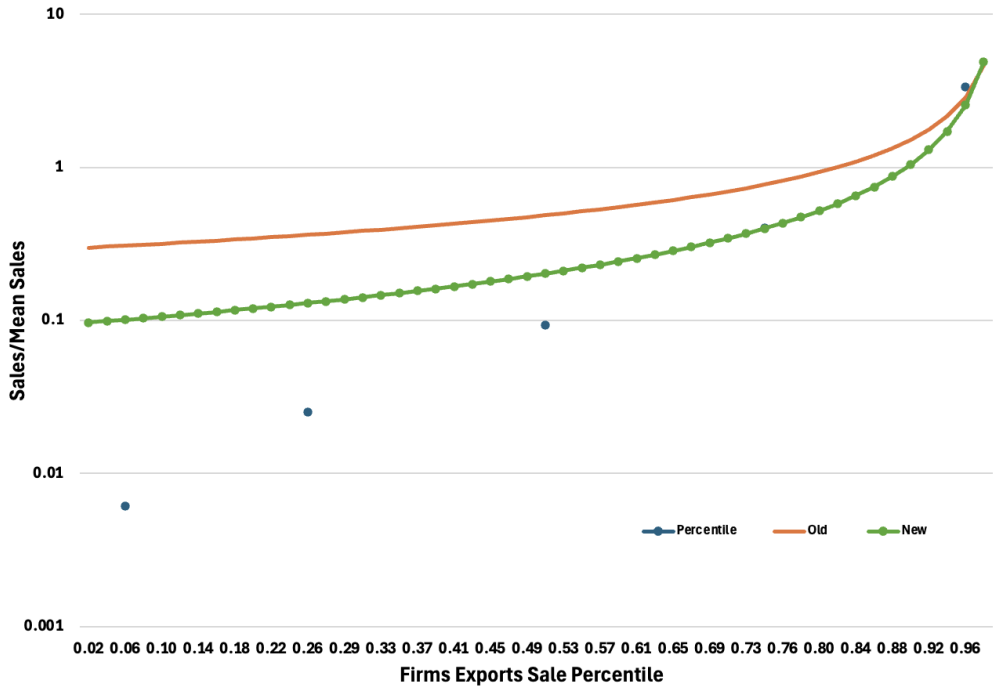


Figure 1: Distribution of Firm Export Sales (CES)

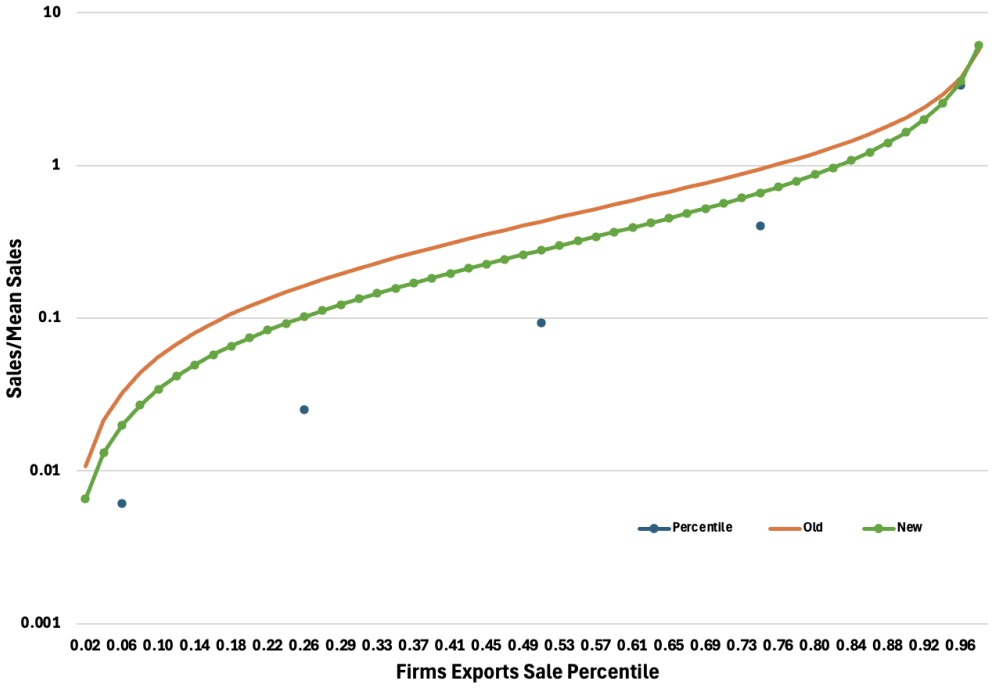
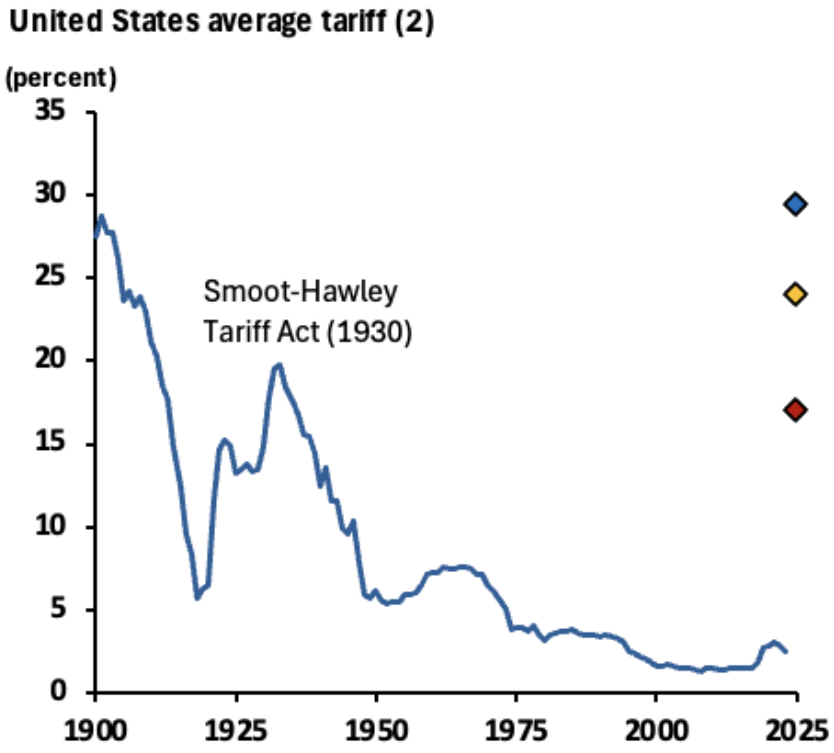


Figure 2: Distribution of Firm Export Sales (generalized CES)

7 Policy Application: How Does the Effect of US Tariff Change?

The new government of the United States under President Donald J. Trump has increased import tariffs on foreign products, reaching the highest level since 1930, with the Smoot-Hawley Tariff Act.



(2) The yellow diamond corresponds to the average tariff after the April 2 announcements. The blue diamond corresponds to the average tariff as of April 12, after the increase to 145% of the tariff on China. The red diamond corresponds to the average tariff as of June 11 (statistical closing date of this Report). Sources: June 2025 IPoM, Central Bank of Chile, US International Trade Commission, and Tax Foundation.

In this case, I study the effect of a 25% increase in tariffs within a model featuring variable markups (generalized CES) is analyzed. Since tariffs are imposed on all companies, regardless of their productivity, the new cost of the iceberg in the original model is $\tau_{ij} \equiv \tau_{ij} + 0.25$, while in the new model it becomes $\tau_{ij}(z) \equiv \bar{z}\tau_{ij}/z + 0.25$.

In Tables 8 and 9, we can observe the effects of US tariffs. By comparing both models, the impact of a 25% tariff increase on goods imported from the US shows a reduction of 50% in the percentage of exports and 48% in the number of firms that export in the original model. In contrast, in the new model, exports decrease by 34% and the number of exporting firms decreases by 42%. These results can be explained by the fact that in the original model, the least productive firms that export still do so, whereas in the new model, these firms are excluded from exporting due to higher iceberg costs. As a result, when tariffs increase for all firms, the productivity of the export cutoff increases by 14% in the original model, compared to just 8% in the new model. This leaves more firms engaged in international trade in the original model than in the new one, as some firms were already excluded in the latter model before the tariff increase. This explains why the export share decreases less in the new model (42%) than in the original model (48%).

Table 8: Effect of US tariffs: Old Model

Model	Old	Old (25% tariffs)	Comparison Old
FracExporters	0.07	0.04	-0.50
ExportShare	0.07	0.04	-0.48
p^*	5.44	5.47	0.01
z_d	0.18	0.18	-0.01
z_x	0.31	0.35	0.14
N	0.17	0.17	0.00
MeanMarkupNonexporters	0.10	0.11	0.07
MeanMarkupExporters	0.21	0.24	0.14

Table 9: Effect of US tariffs: New Model

Model	New	New (25% tariffs)	Comparison New
FracExporters	0.03	0.02	-0.34
ExportShare	0.07	0.04	-0.42
p^*	5.43	5.46	0.01
z_d	0.18	0.18	-0.01
z_x	0.37	0.40	0.08
N	0.17	0.17	-0.01
MeanMarkupNonexporters	0.11	0.06	-0.48
MeanMarkupExporters	0.18	0.20	0.14

8 Conclusion

In recent years, transportation costs have become increasingly important in international trade. Using Chilean data, I analyze firm-level heterogeneity in these costs and find that bigger firms face lower iceberg costs. This contrasts with traditional models, which assume that transportation costs depend only on the origin-destination pair. To address this, I incorporate an iceberg cost that depends on firm productivity into a model of international trade featuring firm-level heterogeneity, monopolistic competition, and variable vs. constant markups. The results show that this modification strengthens the selection effect by raising the productivity cutoff for exporting, aligning well with the data: only a small fraction of firms export, and the distribution of sales is highly concentrated in the right tail. The new model captures these patterns more accurately. Finally, I examine a policy application related to US tariffs, finding that a 25% increase in import tariffs reduces both the percentage of exporting firms and the export share. However, the decline is less pronounced than in a model in which iceberg costs are independent of firm productivity, primarily due to the stronger selection effect.

References

G. Alessandria, H. Choi, and K. J. Ruhl. Trade adjustment dynamics and the welfare gains from trade. *Journal of International Economics*, 131:103458, 2021.

T. Allen. Information frictions in trade. *Econometrica*, 82(6):2041–2083, 2014.

C. Arkolakis, A. Costinot, D. Donaldson, and A. Rodríguez-Clare. The elusive pro-competitive effects of trade. *The Review of Economic Studies*, 86(1):46–80, 2019.

A. B. Bernard, J. Eaton, J. B. Jensen, and S. Kortum. Plants and productivity in international trade. *American economic review*, 93(4):1268–1290, 2003.

A. B. Bernard, J. B. Jensen, S. J. Redding, and P. K. Schott. Firms in international trade. *Journal of Economic perspectives*, 21(3):105–130, 2007.

G. Brancaccio, M. Kalouptsidi, and T. Papageorgiou. Geography, transportation, and endogenous trade costs. *Econometrica*, 88(2):657–691, 2020.

M. A. Clemens and J. G. Williamson. Why did the tariff–growth correlation change after 1950? *Journal of Economic Growth*, 9:5–46, 2004.

J. Eaton, S. Kortum, and F. Kramarz. Dissecting trade: Firms, industries, and export destinations. *American Economic Review*, 94(2):150–154, 2004.

D. Hummels. Transportation costs and international trade in the second era of globalization. *Journal of Economic perspectives*, 21(3):131–154, 2007.

M. J. Melitz. The impact of trade on intra-industry reallocations and aggregate industry productivity. *econometrica*, 71(6):1695–1725, 2003.

M. J. Melitz and G. I. Ottaviano. Market size, trade, and productivity. *The review of economic studies*, 75(1):295–316, 2008.

H. R. Varian. Price discrimination and social welfare. *The American Economic Review*, 75 (4):870–875, 1985.

A Appendix

A.1 Equation (12)

I assume that firm productivity z follows a Pareto distribution:

$$G_i(z) = 1 - (\frac{b_i}{z})^{\theta}, z \geq b_i \tag{21}$$

where b_i is the lower bound of the productivity distribution and θ is the shape parameter. The density function is:

$$g_i(z|z \geq z_{ij}^*) = \frac{\theta b_i^{\theta}}{z^{\theta+1}} \tag{22}$$

Since marginal cost is $c \equiv \frac{w_i \bar{z} \tau_{ij}}{z^2}$ we substitute c into the firm-level sales equation:

$$x(\frac{w_i \bar{z} \tau_{ij}}{z^2}, v, Q, L) = LQ \frac{w_i \bar{z} \tau_{ij}}{z^2} \mu(v) D(\mu(v)/v). \tag{23}$$

Substituting this into the total sales integral:

$$X_{ij} = N_i \int_{z_{ij}}^{\infty} L_j Q_j \frac{w_i \bar{z} \tau_{ij}}{z^2} \mu(v) D(\mu(v)/v) dG_i(z). \tag{24}$$

Changing variables by setting $v = z/z_{ij}^*$ so that $z = v z_{ij}^*$, I get:

$$dz = z_{ij}^* dv \tag{25}$$

Rewriting the integral in terms of v:

$$X_{ij} = N_i L_j Q_j w_i \bar{z} \tau_{ij} \int_1^{\infty} \frac{\mu(v)}{(v z_{ij}^*)^2} D(\mu(v)/v) \frac{\theta b_i^{\theta}}{(v z_{ij}^*)^{\theta+1}} z_{ij} dv. \tag{26}$$

Simplifying:

$$X_{ij} = N_i L_j Q_j w_i \bar{z} \tau_{ij} \theta b_i^{\theta} {z_{ij}}^{-\theta-2} \int_1^{\infty} (\mu(v)/v) D(\mu(v)/v) v^{-\theta-2} dv. \tag{27}$$

Define the constant:

$$\chi = \theta \int_1^{\infty} (\mu(v)/v) D(\mu(v)/v) v^{-\theta-2} dv. \tag{28}$$

Replacing:

$$X_{ij} = \chi N_i L_j Q_j w_i \bar{z} \tau_{ij} b_i^{\theta} {z_{ij}}^{-\theta-2} \tag{29}$$

Substituting $z_{ij} = (\frac{w_i \bar{z} \tau_{ij}}{P_j})^{1/2}$:

$$X_{ij} = \chi N_i L_j Q_j w_i \bar{z} \tau_{ij} b_i^{\theta} ((\frac{w_i \bar{z} \tau_{ij}}{P_j})^{1/2})^{-\theta-2} \tag{30}$$

Rearranging, I obtain equation (12):

$$X_{ij} = \chi N_i b_i^{\theta} (w_i \bar{z} \tau_{ij})^{-\theta/2} L_j Q_j (P_j)^{(\theta+2)/2}, \tag{31}$$

A.2 Equation (14)

From equation (10):

$$\pi(c, v, Q, L) \equiv ((\mu(v) - 1)/\mu(v)) x(c, v, Q, L). \tag{32}$$

And substituting equation (22), (23) and (25) into the total profits integral:

$$\Pi_{ij} = N_i L_j Q_j w_i \bar{z} \tau_{ij} \int_1^{\infty} (\mu(v) - 1/\mu(v)) \frac{\mu(v)}{(v z_{ij}^*)^2} D(\mu(v)/v) \frac{\theta b_i^{\theta}}{(v z_{ij}^*)^{\theta+1}} z_{ij} dv. \tag{33}$$

Simplifying:

$$\Pi_{ij} = N_i L_j Q_j w_i \bar{z} \tau_{ij} \theta b_i^{\theta} {z_{ij}}^{-\theta-2} \int_1^{\infty} (1 - 1/\mu(v)) \mu(v) D(\mu(v)/v) v^{-\theta-3} dv. \tag{34}$$

Define the constant:

$$\pi = \theta \int_1^{\infty} (\mu(v) - 1) D(\mu(v)/v) v^{-\theta-3} dv. \tag{35}$$

Replacing:

$$\Pi_{ij} = \pi N_i L_j Q_j w_i \bar{z} \tau_{ij} b_i^{\theta} {z_{ij}}^{-\theta-2} \tag{36}$$

Substituting $z_{ij} = (\frac{w_i \bar{z} \tau_{ij}}{P_j})^{1/2}$:

$$\Pi_{ij} = \pi N_i L_j Q_j w_i \bar{z} \tau_{ij} b_i^{\theta} ((\frac{w_i \bar{z} \tau_{ij}}{P_j})^{1/2})^{-\theta-2} \tag{37}$$

Rearranging, I obtain equation (14):

$$\Pi_{ij} = \pi N_i b_i^{\theta} (w_i \bar{z} \tau_{ij})^{-\theta/2} L_j Q_j (P_j)^{(\theta+2)/2}, \tag{38}$$