HIAS-E-112

Nonlinear Pricing in the Transport Industry and the Gains from Trade

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September, 2021

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September 18, 2021

Abstract

Recent empirical research documented that there exists a nonlinear pricing phenomenon in the shipping industry. This paper strives to show how this empirical regularity would alter conventional results in trade literature. This paper also shows that when nonlinear pricing in the shipping industry is considered, while the average productivity is higher conducive to the higher welfare level, the gains from trade are generally lower than the situation without. In addition, the model built in this paper offers micro foundations for the additive trade cost and features an endogenous response of shipping charges to the iceberg trade cost, an empirical finding emphasized in Hummels et al. (2009). In a much broader sense, this paper argues that the heterogeneous firm model offers a lens through which traditional results on some interesting objects, for example, gains from trade, could be altered.

Keywords: Nonlinear pricing, Shipping industry, Heterogeneous firms, The gains from trade

JEL Codes: F12, F14, L25, L91, R41

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1 Introduction

Though trade economists have long acknowledged that the shipping charge is part of the trade cost, many view the components of trade cost (*e.g.* tariff rate, shipping charge) as independent, which is clearly at odds with the empirical findings emphasized by Hummels et al. (2009) (*i.e.*, the shipping charges endogenously respond to tariff rate[1]). Based on the heterogeneous firm international trade model, this paper offers a framework that accommodates an endogenous response of shipping charges to the iceberg trade cost at the same time aligning well with the nonlinear pricing phenomenon in the shipping industry, recently documented by Ignatenko (2020). Moreover, this framework shows that the nonlinear pricing in the shipping industry could potentially dampen the gains from trade, though the average productivity is higher after opening to trade.

Among the four components of trade cost, transport attrition, time cost, transaction cost, and tariff, it is sensible to claim that the technological advances in logistics would shrink the proportion of transport attrition and time cost out of the total trade cost, meanwhile constant trade negotiations would limit the size of tariff, leaving the transaction cost as the major component of the barrier to trade flows. This time trend echos Hummels (2007)'s documentation that in the US the transportation expenditure, initially only half of the tariff duties in 1958, grew to be three times higher than the concurrent tariff duties paid by 2004. Additionally, using custom data Hummels (2007) shows that the transportation cost is at least as important as the tariff in terms of impeding trade flows. Therefore, naturally more delicate treatment on the shipping industry is required on how the industry policy on transportation sector and trade policy would stem the flows of world trade.

However, the majority of prevalent trade literature follows the simplification initiated by Samuelson (1954) and does not explicitly model the transport industry, where this paper attempts to fill the gap and examine how this would reshape the conventional results. This paper shows that the nonlinear pricing practice prevailing in shipping industry, an

[1]The anatomy of the trade cost is beautifully synthesized by Spulber (2007) as "the four Ts"—transport attrition, time cost, transaction cost, and tariff.

empirical regularity emphasized by Ignatenko (2020), would provide productive firms with more favorable deals, enabling them to expand more than they would otherwise. This empowerment reinforces the productivity advantages of the productive firms and cripples the survivability of the unproductive firms, thereby raising the entry cutoff of firms, a crucial statistics to the measurement of the gains from trade. Also, more favorable deals would translate into a distorted firm size distribution which many researches attempt to match. In contrast to the preceding work by Ignatenko (2020) and Ardelean and Lugovskyy (2020), this paper yields closed-form general equilibrium effects which clearly shows its welfare implication, after showing the same theoretical results using the Melitz-Chaney model which also hold in the Melitz and Ottaviano (2008) (thereafter MO) framework. The importance of the general equilibrium effects manifests in this paper's results: the positive welfare effect from a "winner-favoring" essence of nonlinear pricing conducive to a higher average productivity is generally offset by the market power distortion from the shipping industry, which is invisible without general equilibrium settings.

This paper connects with many strands of literature. It contributes to the strand of trade literature striving to assess the gains from trade. Starting from the seminal and influential paper by Arkolakis et al. (2012) (thereafter ACR), many other papers discover channels or mechanisms which could potentially modify the gains from trade. Melitz and Redding (2015) argue that the ACR's results are sensitive to firm productivity distribution in a sense that even an truncated version of the Pareto distribution would introduce additional elements into the ACR formula and the routine applying of an intrinsically changing partial trade elasticity with respect to the variable trade cost to the ACR formula would undervalue the gains from trade, especially under the range of values when the variable trade cost is high. Similar results are also uncovered by both Head et al. (2014) and Bas et al. (2017)—a departure of firm heterogeneity from the Pareto distribution fitting the upper tail of firm sales to log-normal distribution which fits the complete distribution of firm sales, naturally gives rise to variable trade elasticity with respect to trade cost. Under the translog preference, Novy (2013) also finds the trade elasticity is a variable. Therefore, without the varying trade elasticity, the canonical trade literature might underestimate the gains from trade. Additionally, Caliendo and Parro (2015) derives analytical expressions for the gains from trade in a world with mutisectors and vertical linkages, showing that the gains from trade would be underestimated without them. In line with the aforementioned literature, this paper discovers a new channel, the nonlinear pricing practice in the transport industry, modifying the assessment of the gains from trade.

This paper also adds to the line of literature attempting to explain the vast existence of an additive trade cost documented by Irarrazabal et al. (2015) and investigates how the additive trade cost would steer the trade flows differently from the conventional multiplicative trade cost. Irarrazabal et al. (2015) show that the elasticity of the quantity elasticity of price with respect to additive trade cost changes along the additive trade cost, the property helps in identifying the additive trade cost. They show quantitatively that the additive trade cost do change the welfare gains assessment. Coşar and Demir (2018) and Fan et al. (2020) consider the additive trade cost when firms choose both quantity and quality of their products. Coşar and Demir (2018) finds that containerization explains a significant amount of the global trade increase. Fan et al. (2020) show that the additive trade cost would affect firms' quality choice differently from the multiplicative trade cost, thereby generating two different trade elasticities in the traditional structural gravity equation. However, all aforementioned papers incorporate the additive trade cost without micro foundations. This paper together with Ignatenko (2020) lay out the micro foundations for the additive trade cost and assign economic meanings to its components in both the Melitz-Ottaviano and Melitz-Chaney frameworks.

This paper also sheds some light on the recent discussion about superstar firms and their implications on the labor share. Freund and Pierola (2015) document that the top several firms account for extraordinarily huge portion of one countries' export and revealed a comparative advantage in a sector can be created by a single firm. Autor et al. (2020) argue that the creative destruction in a heterogeneous firm model contributes to the sales concentration of top firms, which have high markups and a low labor share of value added. The framework in this paper speaks to the very cause of "export superstars" through emphasizing the "winner-favoring" effect of nonlinear pricing in the shipping industry, which amplifies the productivity advantage of big firms abroad and aggravates the lower labor share.

Admittedly, this paper is not the first one to endogenize the transport industry.[2] Ishikawa and Tarui (2018) consider an monopolistic international transportation industry arguing that the freight rate will endogenously respond to tariff changes, thereby, modifing the desired effects that follow. Brancaccio et al. (2020) build a spatial model in global shipping and reveal three mechanisms that would be otherwise absent in the exogenous trade cost models. The work by Kleinert and Spies (2011) and Asturias (2020) point out that the profit maximizing behavior of the shipping companies enable them to switch shipping technology between trade routes of different sizes. Notably, Asturias (2020) assembles an unique data set and its calibration shows that shipping companies tend to use a higher fixed cost but a lower marginal cost technology at routes with increasing trade flows. Despite all their efforts, none of them pay attention to the firmwise shipping charges variations and consider the nonlinear pricing as a main force in modeling the transportation industry's pricing strategy.

The next section lays out the primitives and environment needed to set up the model. Section 3 describes the shipping firm's profit maximizing strategy. Section 4 investigates the welfare implication of nonlinear pricing in the shipping industry in general equilibrium. Section 5 discusses its implication in firm size distribution and gravity. The last section concludes.

2 Primitives and Environment

The specification for consumer utility is the one used in Melitz and Ottaviano (2008) and the individual representative preference is given as:

$$U_j^c = \alpha \int_{\omega \in \Omega_j} q^c(\omega)\, \mathrm{d}\omega - \frac{1}{2}\gamma \int_{\omega \in \Omega_j} (q^c(\omega))^2\, \mathrm{d}\omega - \frac{1}{2}\eta \left(\int_{\omega \in \Omega_j} q^c(\omega)\, \mathrm{d}\omega \right)^2 + q^0. \tag{1}$$

[2] A vast strand of literature investigates this phenomenon in urban economics (see, *e.g.* Behrens et al. (2009)).

where ω is the index of goods in the set Ω_j—the set of goods available in country j. The production technology of the outside good q^0 is linear whose per unit production requires one unit of labor and it's being freely traded. The market for the outside goods is assumed to be perfect competition and we assume consumers have positive demand of the outside goods. From here on, we treat this outside goods as numeraire.

Then utility maximization of an individual preferences yields the following demand for a particular good ω:

$$q(\omega) = \frac{L_j}{\gamma}\left(\alpha - p(\omega) - \eta \int_{\omega \in \Omega_j} q^c(\omega)\, \mathrm{d}\omega\right), \tag{2}$$

where L_j is the population of the destination country. We define the aggregate variables $Q_j^c := \int_{\omega \in \Omega_j} q^c(\omega)\, \mathrm{d}\omega$ and $P_j := \int_{\omega \in \Omega_j} p(\omega)\, \mathrm{d}\omega$. Then the demand becomes:

$$q(\omega) = \frac{L_j}{\gamma}\left(\alpha - p(\omega) - \eta Q_j^c\right). \tag{3}$$

Summing across goods available in country j, whose mass is M_j, yields the following:

$$Q_j^c = \frac{\alpha M_j - P_j}{\gamma + \eta M_j} \tag{4}$$

which connects the two aggregate variables Q_j^c and P_j. Furthermore, the quantity produced by the cutoff manufacturer $q(\varphi^*) = 0$, which will be rationalized by the shipping companies' profit maximization problem, implies there exist p_j^* such that:

$$p_j^* = \alpha - \eta Q_j^c. \tag{5}$$

The shipping industry bears a resemblance to the production sector specification in Krugman (1980), where the shipping firms engage in monopolistic competition which rebates all the profits back to the individuals through their wages.[3] It incurs a fixed cost f_s for the shipping companies to serve a route. The number of shipping firms operating

[3]The monopolistic competition assumption in the shipping industry is to some extent innocuous as Hummels et al. (2009) discover evidence of considerable market power in the shipping industry.

a route from country i to country j is denoted as N_{ij}, which will be determined endogenously by the free-entry conditions for the shipping companies. Because the shipping industry per se is not at the very center of interest in this paper, we simply assume they are homogeneous and having the same productivity. With the above assumptions, it is reasonable to assume the heterogeneous manufacturers who use shipping services pair with shipping firms randomly. Therefore, given a shipping firm, the productivity distribution of its potential customers $G(\varphi)$ (with $g(\varphi)$ being is p.d.f) is the same across all the shipping companies which is common information for all the players. The equilibrium is reached in sequence: in the first stage, free entry from both the shipping industry and the manufacturing industry occur foreseeing their actions in the second stage; then in the second stage, both the manufacturers and the shipping firms optimize their quantity and service given the macro variables.

As in Melitz and Ottaviano (2008) the manufacturers do not incur a fixed cost to export its products to each market. The realization of productivity draw is private information to each manufacturer which can not be observed by the shipping companies. After observing the shipping pricing menu, the manufacturers choose the quantity to export and pay the corresponding shipping fees.

3 Shipping Firm Screening

A typical shipping firm would use a type contingent contract to maximize their profits. Thanks to the revelation principle, the optimal contract for the shipping companies would be the one specifying the outcome pairs $(q(\varphi), T(\varphi))$ and inducing the manufacturers to reveal their true types. The problem can be formulated as follows:

$$\begin{aligned} &\max_{q(\varphi),T(\varphi),\Omega} \int_{\varphi\in\Omega} (T(\varphi) - wvq(\varphi))\,\mathrm{d}G(\varphi) \\ &\text{subject to:} \quad \underbrace{p(\varphi)q(\varphi) - \tau\frac{w}{\varphi}q(\varphi) - T(\varphi)}_{\pi(\varphi)} \geq 0 \quad \forall\varphi\in\Omega \quad \text{(IR)} \\ &p(\varphi)q(\varphi) - \tau\frac{w}{\varphi}q(\varphi) - T(\varphi) \geq p(\hat{\varphi})q(\hat{\varphi}) - \tau\frac{w}{\varphi}q(\hat{\varphi}) - T(\hat{\varphi}) \quad \forall\varphi,\hat{\varphi} \quad \text{(IC)} \end{aligned} \tag{6}$$

where $p(\varphi)$ is the inverse demand for the manufacturer goods from the MO preferences, τ is the standard iceberg trade cost and v is the unit shipping cost in terms of labor. $G(\varphi)$ (with $g(\varphi)$ being its p.d.f) is the distribution of manufacturers.

After checking the single-crossing condition and some simple manipulation (the details are in the appendix), the objective function of shipping companies can be reduced to the following:

$$\max_{q(\varphi),\varphi^*} \int_{\varphi^*}^{\infty} \frac{J_i}{N_{ij}} \left(p(\varphi)q(\varphi) - \tau \frac{w}{\varphi} q(\varphi) - \int_{\varphi^*}^{\varphi} \frac{\tau w q(x)}{x^2} \, \mathrm{d}x - wvq(\varphi) \right) \mathrm{d}G(\varphi), \tag{7}$$

where J_i is the mass of potential manufacturers in country i and N_{ij} is the mass of shipping firms operating the route from country i to country j, both of which are macro variables and taken as given by the shipping firms.

The transformed version after integration by parts is given by:

$$\max_{q(\varphi),\varphi^*} \int_{\varphi^*}^{\infty} \frac{J_i}{N_{ij}} \left[\left((p(\varphi) - \tau \frac{w}{\varphi} - wv) q(\varphi) \right) g(\varphi) - \frac{\tau w q(\varphi)}{\varphi^2} [1 - G(\varphi)] \right] \mathrm{d}\varphi. \tag{8}$$

The Euler Lagrange condition requires a maximization of $q(\varphi)$ over the term under integral in equation (8), which yields:

$$\underbrace{p'q + p}_{\text{marginal revenue}} = \underbrace{\tau \frac{w}{\varphi} + wv}_{\text{marginal social cost}} + \frac{1 - G(\varphi)}{g(\varphi)} \frac{\tau w}{\varphi^2}. \tag{9}$$

As is standard in information economics literature, the incomplete information plugs in a wedge between the marginal revenue and the marginal social cost, thereby distorting the first best allocation. Here in this paper, when the "consumers" become the manufacturers, one additional implication appears—given the same demand, every manufacturer will charge a higher mark-up than the one under perfect competition. The higher mark-up stemming from the market power of the shipping firms has a negative impact on the gains from trade. This higher mark-up, as Autor et al. (2020) claim, is conducive to higher profits, thereby aggravating the already low labor share from the standard heterogeneous firm model.

If the productivity distribution is assumed to be the Pareto distribution with shape parameter θ:

$$G(\varphi) = 1 - \left(\frac{b}{\varphi}\right)^{\theta}, \tag{10}$$

then the equation (9) is simplified as:

$$\alpha - \frac{2\gamma}{L_j} q - \eta Q_j^c = \frac{\tau w}{\theta \varphi} + \frac{\tau w}{\varphi} + wv. \tag{11}$$

The optimization over φ^* yields the following:

$$\left((p(\varphi^*) - \tau \frac{w}{\varphi^*} - wv) q(\varphi^*) \right) g(\varphi^*) - \frac{\tau w q(\varphi^*)}{(\varphi^*)^2} [1 - G(\varphi^*)] = 0. \tag{12}$$

The above equation means the shipping companies with the monopoly power will configure their customer basis to the extent that profits earned from the marginal cutoff manufacturers with productivity φ^*, adjusted by its mass, will be zero. This equation shows the trade-off to include additional manufacturers, which is the marginal gains by adding marginal manufacturers into the customer base and the resulting inframarginal loss by uniformly lowering the transport charges on the inframarginal manufacturers, which resembles the optimal exclusion condition—equation 7 in Luo et al. (2018).[4]

The manufacturers with cutoff productivity φ^* will naturally satisfy both equations (11) and (12), which, together with the Pareto distribution assumption for productivity, lead to the following:

$$\begin{aligned} \left(p(\varphi^*) - \tau \frac{w}{\varphi^*} - wv - \frac{\tau w}{(\varphi^*)^2} \frac{\varphi^*}{\theta} \right) q(\varphi^*) = 0 \\ \frac{\gamma}{L} (q(\varphi^*))^2 = 0, \end{aligned} \tag{13}$$

which shows necessarily the manufacturers with cutoff productivity φ^* will choose to

[4] In fact, the term $\frac{\tau w q(\varphi^*)}{(\varphi^*)^2}$ in equation (12) represents the change of shipping charges to each inframarginal manufacturers, in order to include the marginal manufacturers with productivity φ^* into the customer base. When it is multiplied by $1 - F(\varphi^*)$, together they capture the inframarginal loss. Appendix B offers more intuitive explanations.

produce a zero quantity. This naturally yields the following:

$$p^* = \frac{\tau w}{\theta \varphi^*} + \frac{\tau w}{\varphi^*} + wv = \alpha - \eta Q_j^c. \tag{14}$$

Substitute equation (14) back into equation (11) yields the following:

$$\begin{aligned} p &= \frac{1}{2}\left(p^* + \frac{\tau w}{\theta\varphi} + \frac{\tau w}{\varphi} + wv\right), \\ q &= \frac{L_j}{2\gamma}\left(p^* - \frac{\tau w}{\theta\varphi} - \frac{\tau w}{\varphi} - wv\right). \end{aligned} \tag{15}$$

The equation (11) defines the producing quantity $q(\varphi)$ in terms of the productivity φ and it is increasing in φ, therefore, it satisfies the monotonicity constraint given by equation (52).

Also notice that the first line of equation (15) specifies the pricing scheme for each manufacturers of different levels, which is the average of its own effective marginal cost $\frac{\tau w}{\theta\varphi} + \frac{\tau w}{\varphi} + wv$ and cost cut off p^*. Compared with the counterpart in Melitz and Ottaviano (2008), the effective marginal cost of the manufacturers is lifted up with an additional two terms $\frac{\tau w}{\theta\varphi}$ and wv, which together can be understood as the last unit price charged by shipping companies to the manufacturers. It's worthwhile to take a note that equation (15) echos one of the main advantages of the additive trade cost models, highlighted in Irarrazabal et al. (2015), that the additive trade cost models can naturally yield zero bilateral trade flows with just parsimonious assumptions. They show that a zero bilateral trade flow could happen under additive trade cost with the CES demand if the additive trade cost is so high that even the infinitely productive firm might find it unprofitable to export to some regions. Although here I show the same property holds for the linear demand with this special model specification, in fact it holds for more general demand functions.

PROPOSITION 1. *The incomplete information structure between shipping companies and manufacturers yields a higher mark-up than the perfect competition, given the demand function and naturally yields additive trade cost components which is the unit cost of shipping regardless of the demand specification and the productivity distributions.*

The shipping companies would offer a menu of pair $(q(\varphi), T(\varphi))$ to induce self-selection and the last unit of quantity $\frac{\mathrm{d}T(\varphi)}{\mathrm{d}q(\varphi)}$ would be priced at $\frac{\tau w}{\theta\varphi} + wv$, which can be shown using equation (53):

$$\frac{\mathrm{d}T(\varphi)}{\mathrm{d}q(\varphi)} = \frac{\tau w}{\theta\varphi} + wv. \tag{16}$$

If the information is complete and the shipping industry is competitive, the last unit price would be constant and equal to wv. However, in this environment, the well-known phenomenon "Nonlinear Pricing" in Industrial Organization is captured by the $\frac{\tau w}{\theta\varphi} + v$ term. The most competitive manufacturers get closet to competitive price wv and the last unit price is decreasing in φ meaning the more quantity shipped the less the marginal unit price would be, which in turn reduces the average unit price. This decreasing unit price observed in reality reinforces the advantage of the productive firms, empowering them further to capture a larger market shares.

PROPOSITION 2. *If the common knowledge productivity distribution is Pareto distribution and the realized productivity is private information, the optimal self-selecting contract for the principal is a set of pairs $(q(\varphi), T(\varphi))$, which has the property that $\frac{\mathrm{d}T(\varphi)}{\mathrm{d}q(\varphi)}$ is decreasing in φ.*

The formula for the transfer from the manufacturers to the shipping companies can be derived by simultaneously manipulating equations (15) and (16). Equation (15) defines a monotonic relationship of equilibrium q and φ denoted as $\varphi = \phi(q)$. Then equation (16) can be transformed into:

$$\mathrm{d}T = \left(\frac{\tau w}{\theta\phi(q)} + wv\right)\mathrm{d}q. \tag{17}$$

Taking indefinite integration over both sides of the above equation yields the following:

$$T(q) = \frac{q\left[p^* - \frac{\gamma}{L}q + \theta wv\right]}{\theta + 1} + C = \frac{(p + \theta wv)q}{\theta + 1} \tag{18}$$

where C is a constant and it will be equal to zero because the manufacturers with cutoff productivity will produce zero quantity in this model.[5] After the manufacturers obtain

[5]This approach is essentially the same as in Maskin and Riley (1984). To see this, following the

the productivity draws, the ones whose draws are above the cutoff level φ^* will enter the markets. Just as the IR' condition implies, the shipping companies will accommodate all the entering manufacturers by making the marginal player indifferent between quit and stay. Also the marginal player will have a demand exactly equals to zero, indicating that there is no surplus which the shipping companies can extract in the means of a lump-sum transfer.

Inspection of equation (18) reveals that the total amount charged by the shipping firms in this model is no longer proportional to the quantity shipped in a conventional assumption in traditional trade literature, but a weighted average of the sales of the manufacturer and the variable cost incurred in shipping. This shipping payment potentially affects the profitability of the manufacturers and in turn impacts the mass of manufacturers in the general equilibrium.

Also notice that the average unit price is given as:

$$\frac{T(q)}{q} = \frac{(p(q) + \theta wv)}{\theta + 1} \tag{19}$$

which is indeed decreasing in q comfirming the "Nonlinear Pricing" result and it differs from the otherwise competitive average unit price v. It is also increasing in the price of goods which is in line with the empirical finding in Hummels et al. (2009). Conveniently, substituting equation (15) into equation (19) yields a formula showing the relationship between the unit freight rate and the iceberg trade cost τ showing that freight rate endogenously responds to the change in the iceberg trade cost.

In conventional trade literature, however, where both the tariff and the freight rate are conceived to be two multiplicative components of τ, the changes in the tariff would not affect the freight rate, because they are independent from each other, a property which is at odds with the empirical findings documented by Hummels et al. (2009) that

method in Maskin and Riley (1984), taking definite integral over $\frac{\mathrm{d}T}{\mathrm{d}q}$ yields $T(q) - T(q^*) = \frac{(p+\theta wv)q}{\theta+1}$, where $T(q^*)$ is the transport charges paid by the least productive firm and its value is given by $W(\varphi^*) = r(\varphi^*) - \frac{\tau w}{\varphi^*}q(\varphi^*) - T(q(\varphi^*))$. Equation (13) shows that the cutoff manufacturers will produce zero quantity, which immediately implies both $r(\varphi^*)$ and $q(\varphi^*)$ are 0. After setting $W(\varphi*) = 0$ as in Maskin and Riley (1984), $T(q(\varphi^*)) = 0$ ensues, which gives the same profit maximizing pricing scheme as in the main content.

shipping companies tend to set a higher freight rate on goods facing a higher tariff. The inability of capturing the positive endogenous change of the freight rate with respect to tariff in the traditional trade model does not merely stem from the lack of modeling the transport industry. Even imposing a monopolistic structure on the transport industry in the traditional trade model, the holistic multiplicative nature of both the tariff and the freight rate would imply that a higher tariff leads to a lower freight rate, which is not supported by the empirical findings in Hummels et al. (2009).

Equations (11) and (18) together characterize the surplus-splitting mechanism between shipping companies and manufacturers.

4 Welfare Implications

After knowing the screening strategy of the shipping firms and the optimal response from the manufacturers, it is ready to analyze its effect on the gains from trade. Because nonlinear pricing in the shipping industry introduces two additional terms, namely $\frac{\tau w}{\theta \varphi}$ and vw, a variant of Melitz and Ottaviano (2008), capable of incorporating the unit cost of shipping, is established as a comparison benchmark. To streamline the analysis, from now on, the variables will have a subscript, when necessary, with the form ij meaning the manufacturers from the home country i to the destination country j.

4.1 Benchmark

The benchmark model is a variant of the original Melitz and Ottaviano (2008) model with an additional requirement that goods need to incur a shipping cost to be distributed, or alternatively it can be interpreted as the shipping industry is perfectly competitive. The profits maximization of the manufacturers yields the following:

$$p'q + p = \frac{w}{\varphi} + wv \tag{20}$$

The right hand side of the equation is the total social cost consisting of the unit cost of production and the unit cost of shipping, which can be transformed into the following:

$$
\begin{aligned}
p(\varphi) &= \frac{1}{2}\left(\alpha - \eta Q_j^c + \frac{w}{\varphi} + wv\right), \\
q(\varphi) &= \frac{L_j}{2\gamma}\left(\alpha - \eta Q_j^c - \frac{w}{\varphi} - wv\right).
\end{aligned} \tag{21}
$$

Comparing to the counterparts in the original Melitz and Ottaviano (2008) model, the additional additive term wv, surprisingly does not break the tractability of the general equilibrium objects. Their expressions can be found in the appendix. Typically, the expected profits under a closed economy have the following expression:

$$
\begin{aligned}
\pi_j^D &= \int_{\varphi_{jj}^*}^{\infty} \frac{L_j}{4\gamma}\left(\alpha - \eta Q_j^c - \frac{w}{\varphi} - wv\right)^2 \theta \frac{b_j^\theta}{\varphi^{\theta+1}}\,\mathrm{d}\varphi \\
&= \frac{b_j^\theta L_j w^2}{2\gamma(\theta+1)(\theta+2)(\varphi_{jj}^*)^{\theta+2}},
\end{aligned} \tag{22}
$$

which is the same as the one in Melitz and Ottaviano (2008). The inclusion of an unit cost of shipping does not diminish the manufacturers' profitability and it is perfectly absorbed into the price cutoff. As a result, the benchmark here shares the same closed-economy productivity cutoff:

$$
\varphi_{jj}^{DC} = \left[\frac{b_j^\theta L_j w}{2\gamma(\theta+1)(\theta+2)f_e}\right]^{\frac{1}{\theta+2}}. \tag{23}
$$

The indirect utility function is given as follows:

$$
U^D = 1 + \frac{1}{2\eta}\left(\alpha - v - \frac{1}{\varphi_{ii}^*}\right)\left(\alpha - v - \frac{\theta+1}{(\theta+2)\varphi_{ii}^*}\right). \tag{24}
$$

The inclusion of the unit cost of shipping does not structurally change the welfare expression and the expected profits remain the same as in the original MO model. In the same vein, if the unit shipping cost is assumed to be the same, both domestically and abroad, the domestic productivity cutoff under an open economy will be the same as in the original MO model, which can be expressed in this paper's notation as:

$$\varphi_{jj}^{DO} = \left(\frac{\theta}{\theta+1} \frac{\lambda L_j(\tau_{ji}^{\theta}\tau_{ij}^{\theta} - 1)}{\tau_{ij}^{\theta}(\tau_{ji}^{\theta} - 1)} \right)^{\frac{1}{\theta+2}}, \tag{25}$$

where $\lambda := \frac{b^{\theta}}{(4\gamma\theta+2\gamma\theta^2)f_e}$. The indirect utility function under an open economy is the same as the one under a closed economy and the gains from trade manifests as a higher domestic productivity cutoff.

4.2 Nonlinear Pricing on Foreign Shipping Routes – The Intermediate Model

This setting can be viewed as an intermediate step to understanding the inner workings of nonlinear pricing in the shipping industry. It can be interpreted as the manufacturers distributing locally themselves, whereas, shipping services are used to ship goods abroad, which typically captures the real situation of small countries or the situation where the entry cost of shipping domestically is close to zero, therefore, the domestic shipping market is almost perfectly competitive. Under the closed economy where the manufacturers bear the cost of shipping themselves, the equilibrium remains the same as in the benchmark. After the countries in the two-country model are open to trade, under the assumption that the unit shipping cost is the same both domestically and abroad, the productivity cutoff is connected as follows:

$$\theta\varphi_{ji}^{*} = (\theta+1)\tau_{ji}\varphi_{ii}^{*} \quad \forall\, i, j. \tag{26}$$

The above equation reflects the distortion from the market power in the foreign shipping market. It shows that under nonlinear pricing in international shipping, ceteris paribus, only more productive manufacturers are able to overcome the additional wedge from nonlinear pricing to export, thereby reducing the expected profits from exporting. A manufacturer in country j with productivity $\varphi_{ji} = \tau_{ji}\varphi_{ii}^{*}$—who is able to export when there is no market power in the shipping industry—cannot afford to pay the information wedge to export. This market power distortion dampens the gains from trade.

To examine whether a single sufficient statistics exists as in the benchmark model, we denote the term $\frac{\tau w}{\theta\varphi}+\frac{\tau w}{\varphi}+wv$ as the effective marginal cost c:

$$c(\varphi)=\frac{\tau w}{\theta\varphi}+\frac{\tau w}{\varphi}+wv=\frac{\theta+1}{\theta}\frac{\tau w}{\varphi}+wv. \tag{27}$$

Then the marginal cost distribution of manufacturers selling domestically is given as follows:

$$\begin{aligned} P(c_{ii}\leq C) &= P(\frac{w}{\varphi}+wv\leq C)=P(\varphi\geq\frac{w}{C-wv}) \\ &= \left(\frac{\varphi_{ii}^*(C-wv)}{w}\right)^{\theta} \quad \text{with support: } c_{ii}\in(wv,\frac{w}{\varphi_{ii}^*}+wv]. \end{aligned} \tag{28}$$

The marginal cost distribution of manufacturers selling abroad is given as follows:

$$\begin{aligned} P(c_{ji}\leq C) &= P(\frac{\tau_{ji}w}{\theta\varphi}+\frac{\tau_{ji}w}{\varphi}+wv\leq C)=P(\varphi\geq\frac{\tau_{ij}w(\theta+1)}{\theta(C-wv)}) \\ &= \left(\frac{\varphi_{ji}^*\theta(C-wv)}{\tau_{ji}w(\theta+1)}\right)^{\theta} \text{ with support: } c_{ji}\in(wv,\frac{\tau_{ji}w(\theta+1)}{\theta\varphi_{ji}^*}+wv] \\ &= \left(\frac{\varphi_{ii}^*(C-wv)}{w}\right)^{\theta} \text{ with support: } c_{ii}\in(wv,\frac{w}{\varphi_{ii}^*}+wv]. \end{aligned} \tag{29}$$

The price distribution of manufacturers, regardless of origin, is the same, so the macro variables including the indirect utility function in a closed economy remains the same in an open economy, where nonlinear pricing is exercised on foreign shipping. As a result, like in the benchmark model, the only sufficient statistic for a welfare evaluation is the countries' domestic productivity cutoff.

The free entry conditions that determine the productivity cutoffs in the open economy are given as follows:

$$\begin{aligned} \frac{b^\theta L_j w^2}{2\gamma(\theta+1)(\theta+2)(\varphi_{jj}^*)^{\theta+2}}+\frac{b^\theta L_i\tau_{ji}^2 w^2}{2\gamma\theta(\theta+2)(\varphi_{ji}^*)^{\theta+2}} &= wf_e \\ \frac{b^\theta L_i w^2}{2\gamma(\theta+1)(\theta+2)(\varphi_{ii}^*)^{\theta+2}}+\frac{b^\theta L_j\tau_{ij}^2 w^2}{2\gamma\theta(\theta+2)(\varphi_{ij}^*)^{\theta+2}} &= wf_e \end{aligned} \tag{30}$$

which gives the following domestic productivity cutoff:

$$(\varphi_{ii}^*)^{\theta+2} = \frac{\theta}{\theta+1} \frac{\lambda L_i \left(\tau_{ij}^\theta \tau_{ji}^\theta - \left(\frac{\theta}{\theta+1}\right)^{2\theta+2}\right)}{\tau_{ji}^\theta (\tau_{ij}^\theta - \left(\frac{\theta}{\theta+1}\right)^{\theta+1})} \quad \forall i,j. \tag{31}$$

The relative magnitude of the above formula and the one in the benchmark model depends on the relative magnitude of τ_{ij}, τ_{ji} and θ. At first sight, this result seems at odds with the negative effect of the market power in the shipping industry, because the market power distortion and the higher mark-up thereof implies a lower productivity cutoff. This oddity reveals a countervailing effect from nonlinear pricing positively affects the welfare, which is specific to the heterogeneous firms model. As emphasized in the section of shipping firms' pricing strategy, the nonlinear pricing in the shipping industry offers rents to more productive manufacturers empowering their already advantageous productivity strength and crowding out the more unproductive manufacturers than without, thereby lifting up the average productivity of the manufacturing sector. Comparing the productivity cutoff in equation (31) and its counterpart in the benchmark model, we can arrive at the following proposition:

PROPOSITION 3. *In a model where only international shipping uses shipping services,*

1. $\tau_{ji} \geq \tau_{ij} \Rightarrow \varphi_{ii}^* < \varphi_{ii}^{DO} \Rightarrow U^* < U^D \quad \forall i,j$;
2. $\tau_{ji} < \tau_{ij}$ *and* θ *is reasonably valued* $\Rightarrow \varphi_{ii}^* > \varphi_{ii}^{DO} \Rightarrow U^* > U^D \quad \forall i,j.$

The proof of the above proposition is offered in the appendix. Inspection of equations (11) and (26) reveals that the iceberg trade cost performs like a multiplier of the market power distortion. Higher τ_{ji} means a higher mark-up distortion from manufacturers in country j. Consumers are worse off in country i, whereas the additional profitability is rebated to country j, thereby lowering the overall gains from trade for country i. For the positive effect to reverse the negative effect from nonlinear pricing, a sufficient condition, on top of $\tau_{ji} < \tau_{ij}$, is to have θ reasonably valued, so that the negative effect is relatively small, as highlighted in equation (16). Intuitively, the above proposition shows that there is a possibility the positive effect could outweigh the negative effects, though it requires far more strict condition for welfare being higher than being lower. This stringency of conditions is natural, given that incomplete information adds a cost wedge to every manufacturer, except the most productive one compared to the benchmark.

4.3 Nonlinear Pricing on both Domestic Shipping and Foreign Shipping Routes – The Full Model

This situation corresponds to the case where both domestic shipping and foreign shipping use shipping services, which is more appropriate to capture the reality in large countries. It provides some additional effects which are active but not visible in the previous analysis. To ensure consistency with the previous analysis and highlight the impact of nonlinear pricing, the unit cost of shipping domestically and internationally is assumed to be the same.[6] Additional analysis about an unequal unit cost of shipping is offered in the appendix. Whether this assumption is too strong or approximately captures the reality is a valuable empirical question which is not the focus of this paper.

To start with, consider a closed economy where the shipping service is used to distribute goods. All the macro variables can be derived following the steps in the benchmark model, which are given in the appendix. Typically, the expected profits are given as following:

$$\pi_i = \frac{b_i^\theta L_j \tau_{ii}^2 w^2}{(4\gamma\theta + 2\gamma\theta^2)(\varphi_{ii}^*)^{\theta+2}} \tag{32}$$

which is higher than its counterpart in the benchmark model, provided φ_{ii}^* is fixed. Though the nonlinear pricing in the shipping service enables shipping firms to split more surplus, as shown in equation (18), the profitability of manufacturers is actually higher because nonlinear pricing reinforces the productivity advantage of the productive manufacturers by lower marginal shipping charges. These decreasing marginal shipping charges renders more advantages over the unproductive firms, enabling the productive ones to earn more profits relatively. This relative profitability from the nonlinear pricing em-

[6]The empirical analysis in Asturias (2020) shows that the marginal cost of shipping is only weakly decreasing along the trade flows which is inversely related with distance. Therefore, it is relatively safe to assume that the unit cost of shipping is constant, regardless of the distance of shipping.

powers the productive ones to crowd out more unproductive firms. As a result, a higher productivity cutoff ensues:

$$\varphi_{ii}^* = \left[\frac{L_i b_i^\theta}{2\theta(\theta+2)\gamma f_e}\right]^{1/(\theta+2)} > \varphi_{ii}^{DC}. \tag{33}$$

Higher profitability and higher productivity cutoff confirm that the nonlinear pricing in the shipping industry though stemming from the market power does lead to a higher productivity cutoff which is conducive to a higher welfare level. However this higher average productivity has a welfare cost which is active but veiled by multiple forces in the intermediate model. Higher productivity cutoff naturally implies fewer varieties of available goods, which is confirmed as following:

$$M_i = \frac{2\gamma(\alpha\theta\varphi_{ii}^* - \theta - 1 - v\theta\varphi_{ii}^*)}{\eta} < M_i^D. \tag{34}$$

Up to this stage, all the components impacting the gains from trade, as argued by Feenstra (2018), have been shown as being affected by the nonlinear pricing in the shipping industry—higher mark-up, higher average productivity, and fewer goods varieties. Their combined effects will be discussed later.

The profits earned by the shipping firms is given as:

$$\begin{aligned}\Pi(N_{ii}) &= \max_{q(\varphi),\varphi^*} \int_{\varphi_{ii}^*}^{\infty} \frac{J_i}{N_{ii}} \left[\frac{(p+\theta wv)q}{\theta+1} - wvq\right] \mathrm{d}G(\varphi) \\ &= \frac{L_i w_i(\theta+1)(\alpha\theta\varphi_{ii}^* - w_i(v\theta\varphi_{ii}^* + \theta + 1))}{N_{ii}\eta\theta^2(\theta+2)(\varphi_{ii}^*)^2}.\end{aligned} \tag{35}$$

The free entry condition for the shipping industry $\Pi(N_{ii}) = w_i f_s$ yields the expression for the number of active shipping firms:

$$N_{ii} = \frac{L_i(\theta+1)(\alpha\theta\varphi_{ii}^* - w_i(v\theta\varphi_{ii}^* + \theta + 1))}{f_s\eta\theta^2(\theta+2)(\varphi_{ii}^*)^2}. \tag{36}$$

This is because all the profits accrued in the shipping industry are rebated to consumers as wages and wage is the only source of income for each individual. Thereafter, the indirect utility function under a closed economy could be expressed as the parameter values and entry cutoff φ_{ii}^*:

$$U = 1 + \frac{1}{2\eta}\left(\alpha - v - \frac{\theta+1}{\theta\varphi_{ii}^*}\right)\left(\alpha - v - \frac{(\theta+1)^2}{\theta(\theta+2)\varphi_{ii}^*}\right) < U^D \tag{37}$$

The welfare level is lower than the counterpart in the benchmark model, meaning the negative effects from nonlinear pricing outstrips the positive one.

Like in the intermediate model, the open economy version shares the same macro variables as the closed economy, including the indirect utility function. The productivity cutoffs are given as follows:

$$\varphi_{ii}^* = \left(\frac{\lambda L_i(\tau_{ij}^\theta\tau_{ji}^\theta - 1)}{\tau_{ji}^\theta(\tau_{ij}^\theta - 1)}\right)^{\frac{1}{\theta+2}}, \tag{38}$$

$$\varphi_{ji}^* = \left(\frac{\lambda L_i\tau_{ji}^2(\tau_{ij}^\theta\tau_{ji}^\theta - 1)}{\tau_{ij}^\theta - 1}\right)^{\frac{1}{\theta+2}}. \tag{39}$$

Comparing the entry cutoff under both the closed economy and the open economy reveals that, as in the standard trade model, opening to trade increases the entry cutoff selecting more productive firms into the market. The counterpart in the benchmark model is as follows:

$$\varphi_{ii}^{DO} = \left(\frac{\theta}{\theta+1}\frac{\lambda L_i(\tau_{ij}^\theta\tau_{ji}^\theta - 1)}{\tau_{ji}^\theta(\tau_{ij}^\theta - 1)}\right)^{\frac{1}{\theta+2}} < \varphi_{ii}^*. \tag{40}$$

The conclusion reached in the closed economy holds in the open economy, as the negative effects from nonlinear pricing offset the positive one. Nonlinear pricing will dampen the gains from trade.

5 Firm Size Distribution and Gravity

The nonlinear pricing phenomenon has a famous property in that it offers an increasing rent along the type of manufacturers to induce self-revealing, which should translate into a sales advantage for the higher type of firms because they are given a favorable deal by the shipping company. The firm sales is given as follows:

$$r_{ij}(\varphi) = p_{ij}(\varphi)q_{ij}(\varphi) = \frac{L_j}{4\gamma}\left[(p_j^*)^2 - \left(\frac{\tau_{ij}w_i}{\theta\varphi} + \frac{\tau_{ij}w_i}{\varphi} + w_i v\right)^2\right]. \tag{41}$$

The partial derivative of the firm destination-specific sales with respect to productivity is:

$$\frac{\partial r_{ij}(\varphi)}{\partial\varphi} = \frac{L_j w_i^2 \tau_{ij}^2}{2\gamma\varphi^3}\frac{(\theta+1)^2}{\theta^2} + \frac{L_j w_i^2(\theta+1)\tau_{ij}v}{2\gamma\theta\varphi^2} > \frac{L_j w_i^2\tau_{ij}^2}{2\gamma\varphi^3} \tag{42}$$

where $\frac{L_j w_i^2 \tau_{ij}^2}{2\gamma\varphi^3}$ is the counterpart in Melitz and Ottaviano (2008). As anticipated in the beginning of this section, the same level of productivity difference would translate into a higher sales advantage in the presence of nonlinear pricing. Even when v is set to be 0, the other functioning term $\frac{\tau_{ij}w_i}{\theta\varphi}$ introduced by nonlinear pricing elevates the effect of the marginal productivity growth on sales to a constant rate $\frac{(\theta+1)^2}{\theta^2}$ over its counterpart in MO, regardless of the initial productivity level.

To highlight the crucial role of the nonlinear pricing practice from the shipping industry in shaping the firm size distribution, we consider two manufacturers whose productivity are connected as $\varphi_1 = k\varphi_2$ $(k > 1)$. To yield a stark contrast to conventional results (or to obviate the unnecessary complexity), manufacturers' selling to the local market follow the same structure as in the original MO model. Similar qualitative results can be attained using the setting in the benchmark and the marginal insights do not warrant the additional complexity incurred. The domestic sales difference between these two manufacturers is given as:

$$r_{ii}(\varphi_1) - r_{ii}(\varphi_2) = \frac{L_i}{4\gamma}\left[\left(\frac{w_i}{\varphi_2}\right)^2 - \left(\frac{w_i}{\varphi_1}\right)^2\right] \tag{43}$$

$$= \frac{L_i}{4\gamma}\left[\left(1 - \frac{1}{k^2}\right)\left(\frac{w_i}{\varphi_2}\right)^2\right]. \tag{44}$$

The sales difference of those two firms in country j is given as follows:

$$r_{ij}(\varphi_1) - r_{ij}(\varphi_2) = \frac{L_j}{4\gamma}\left[\left(\frac{\tau_{ij}w_i}{\theta\varphi_2} + \frac{\tau_{ij}w_i}{\varphi_2} + w_i v\right)^2 - \left(\frac{\tau_{ij}w_i}{\theta\varphi_1} + \frac{\tau_{ij}w_i}{\varphi_1} + w_i v\right)^2\right] \tag{45}$$

$$= \frac{L_j}{4\gamma}\left[\left(\frac{\theta+1}{\theta}\right)^2\left(1-\frac{1}{k^2}\right)\left(\frac{\tau_{ij}w_i}{\varphi_2}\right)^2 + 2w_i v\left(\frac{\theta+1}{\theta}\right)\left(1-\frac{1}{k}\right)\left(\frac{\tau_{ij}w_i}{\varphi_2}\right)\right]. \tag{46}$$

Taking the ratio of these two differences yields the following:

$$\frac{r_{ij}(\varphi_1) - r_{ij}(\varphi_2)}{r_{ii}(\varphi_1) - r_{ii}(\varphi_2)} = \frac{L_j}{L_i}\left[\left(\frac{\theta+1}{\theta}\right)^2 \tau_{ij}^2 + 2v\left(\frac{\theta+1}{\theta}\right)\left(1+\frac{1}{k}\right)^{-1}\tau_{ij}\varphi_2\right]. \tag{47}$$

To investigate the effect from two novel terms introduced by Nonlinear Pricing one by one, first we set $v = 0$. The sales difference ratio becomes $\frac{L_j}{L_i}\left[\left(\frac{\theta+1}{\theta}\right)^2 \tau_{ij}^2\right]$ which is $\left(\frac{\theta+1}{\theta}\right)^2$ times larger than $\frac{L_j}{L_i}\left(\tau_{ij}^2\right)$ the counterpart in the Melitz and Ottaviano (2008) model. This result remains even when $r_{ij}(\varphi_2)$ and $r_{ii}(\varphi_2)$ are replaced by average sales in the corresponding markets. This implies that nonlinear pricing indeed magnifies the productivity advantage of the more productive firms and translate it into higher sales than it otherwise would be. This effect is reinforced when v is not zero by adding a new term which is increasing in v. This magnification effect from the nonlinear pricing practice in the shipping industry helps to explain the empirical fact that the top exporters are so big that they are dominant in shaping a country's comparative advantage, as documented by Freund and Pierola (2015). They are big not because they are way more productive but because they receive more favorable deals than their underdogs when procuring intermediate services, which reinforces their advantage.

Additionally, equation (47) implies the sales-magnifying effect is responsive to the value of θ—the productivity dispersion parameter. As θ increases, the manufacturers are increasingly homogeneous, the sales-magnifying effect from the nonlinear pricing dwindles. As a side note, the other effects affecting the welfare evaluation, as in last section, are not active here, because those effects affects manufacturers in the destination market from the same country equally, and the sales difference eliminates them.

The bilateral trade flow from country i to country j is given by:

$$\begin{aligned} X_{ij} &= \int_{\varphi_{ij}^*}^{\infty} J_i p_{ij}(\varphi) q_{ij}(\varphi)\, \mathrm{d}G_i(\varphi) \\ &= \frac{b_i^\theta J_i L_j w_i^2}{\tau_{ij}^\theta} \left[\frac{(1+\theta)^2}{2\gamma\theta^2(2+\theta)(\varphi_{jj}^*)^{\theta+2}} + \frac{v}{2\gamma\theta(\varphi_{jj}^*)^{\theta+1}} \right] \end{aligned} \tag{48}$$

This bilateral trade flow resembles the gravity equation in that it decreases with respect to the iceberg trade cost and increases with the destination size when holding destination entry cutoff φ_{jj}^* as fixed. Whereas, if φ_{jj}^* is not held to be fixed, though it is still robust the bilateral trade flow decreases with the iceberg trade cost τ_{ij}, it will only increase with the destination size in a relatively small order. Generally, an increase in v will reduce the bilateral trade flow X_{ij} because an increase of v will dampen both the manufacturers' sales and the number of entrants, which directly affects the volume of bilateral trade flow, provided that v does not affect cutoff levels, as shown in equation (39). However, there exist certain cutoff levels which lift the bilateral trade flow by increasing the number of entrants, which is particularly so when the selection into the export market effect is small. Intuitively, the number of entrants in the home country is jointly determined by the number of active firms in the home and in the foreign, the latter of which can be branded as import competition effect from the foreign markets. The hike of v will reduce the active firms in both the home and foreign markets. The ensued abatement of the import competition will stimulate the entering of domestic entrants, which potentially could outweigh the negative effect stemming from the hike of v.

Equation (48) can be rewritten as follows, so that it could be used in empirical analysis:

$$\frac{X_{ij}}{X_{jj}} = \frac{b_i^\theta J_i w_i^2}{b_j^\theta J_j w_j^2} \tau_{ij}^{-\theta}. \tag{49}$$

The above equation shows that the trade elasticity of multiplicative trade cost θ can be estimated using the standard fixed effect gravity approach.

6 Conclusion

This paper provides a closed-form general equilibrium framework building on the workhorse Melitz-Ottaviano model to show that the nonlinear pricing practice in the shipping industry, an empirical regularity just documented recently, does reshape the conventional results. More favorable deals toward the more productive manufacturers would enable them to expand their sales more than they would be able to do otherwise. This helps to explain why the top firms are so extraordinarily large that they are crucial in shaping one country's comparative advantage and why there is a shift from labor returns to profits as globalization deepens, as documented by Autor et al. (2020). The harsher competition crowds out the more unproductive firms lifting up the average productivity in the manufacturing industry but the lesser variety of available goods ensues and a higher mark-up from the market power in the shipping sector offsets the productivity gain. This result would not be possible without a closed-form general equilibrium model and it suggests a policy intervention into the transport industry to amplify the gains from trade liberalization.

By introducing a monopolistic competitive shipping industry, this novel model yields several properties which are more in line with some empirical findings. The endogenous additive pricing structure naturally gives rise to the possibility of zero-trade volumes between country pairs with only parsimonious assumptions. The optimal unit pricing formula shows that the shipping firms would set a higher unit freight rate for goods facing a higher tariff, a property traditional trade model unable to generate even having a shipping industry with market powers.

Fitting this paper into a broader picture, contrary to what ACR claims, it shows that a heterogeneous firm model does introduce new implications and it opens a valley through which several channels could potentially yield alternative results, which are not possible under the homogeneous firm Ricardian setting.

This paper has established a framework aligned well with various empirical studies and has shown that nonlinear pricing has a complicated but significant impact on the gains from trade. Therefore, a possible extension to this paper is to use real-time data to quantify the model and assess how countries with different characteristics will be affected heterogenously.

References

Ardelean, A. and Lugovskyy, V. (2020). Do Larger Importing Firms Face Lower Freight Rates? *SSRN Electronic Journal*.

Arkolakis, C., Costinot, A., and Rodríguez-Clare, A. (2012). New trade models, same old gains? *American Economic Review*, 102(1):94–130.

Asturias, J. (2020). Endogenous transportation costs. *European Economic Review*, 123:103366.

Autor, D. H., Dorn, D., Katz, L. F., Patterson, C., and Reenen, J. V. (2020). The fall of the labor share and the rise of superstar firms. *Quarterly Journal of Economics*, 135(2):645–709.

Bas, M., Mayer, T., and Thoenig, M. (2017). From micro to macro: Demand, supply, and heterogeneity in the trade elasticity. *Journal of International Economics*, 108:1–19.

Behrens, K., Gaigné, C., and Thisse, J. F. (2009). Industry location and welfare when transport costs are endogenous. *Journal of Urban Economics*, 65(2):195–208.

Brancaccio, G., Kalouptsidi, M., and Papageorgiou, T. (2020). Geography, Transportation, and Endogenous Trade Costs. *Econometrica*, 88(2):657–691.

Caliendo, L. and Parro, F. (2015). Estimates of the trade and welfare effects of NAFTA. *Review of Economic Studies*, 82(1):1–44.

Coşar, A. K. and Demir, B. (2018). Shipping inside the box: Containerization and trade. *Journal of International Economics*, 114:331–345.

Fan, H., Li, Y. A., Xu, S., and Yeaple, S. R. (2020). Quality, variable markups, and welfare: A quantitative general equilibrium analysis of export prices. *Journal of International Economics*, 125.

Feenstra, R. C. (2018). Alternative sources of the gains from international trade: Variety, creative destruction, and markups. *Journal of Economic Perspectives*, 32(2):25–45.

Freund, C. and Pierola, M. D. (2015). Export superstars. *Review of Economics and Statistics*, 97(5):1023–1032.

Head, K., Mayer, T., and Thoenig, M. (2014). Welfare and trade without pareto. *American Economic Review*, 104(5):310–316.

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

Hummels, D., Lugovskyy, V., and Skiba, A. (2009). The trade reducing effects of market power in international shipping. *Journal of Development Economics*, 89(1):84–97.

Ignatenko, A. (2020). Price Discrimination in International Transportation: Evidence and Implications.

Irarrazabal, A., Moxnes, A., and Opromolla, L. D. (2015). The tip of the iceberg: A quantitative framework for estimating trade costs. *Review of Economics and Statistics*, 97(4):777–792.

Ishikawa, J. and Tarui, N. (2018). Backfiring with backhaul problems: Trade and industrial policies with endogenous transport costs. *Journal of International Economics*, 111:81–98.

Kleinert, J. and Spies, J. (2011). Endogenous Transport Costs in International Trade.

Krugman, P. (1980). Scale economies, product differentiation, and the pattern of trade. *American Economic Review*, 70(5):950–959.

Luo, Y., Perrigne, I., and Vuong, Q. (2018). Structural analysis of nonlinear pricing. *Journal of Political Economy*, 126(6):2523–2568.

Maskin, E. and Riley, J. (1984). Monopoly with Incomplete Information. *The RAND Journal of Economics*, 15(2):171.

Melitz, M. J. and Ottaviano, G. I. (2008). Market size, trade, and productivity. *Review of Economic Studies*, 75(1):295–316.

Melitz, M. J. and Redding, S. J. (2015). New trade models, new welfare implications. *American Economic Review*, 105(3):1105–1146.

Novy, D. (2013). International trade without CES: Estimating translog gravity. *Journal of International Economics*, 89(2):271–282.

Samuelson, P. A. (1954). The transfer problem and transport costs, II: Analysis of effects of trade impediments. *The Economic Journal*, 64(254):264–289.

Spulber, D. F. (2007). *Global competitive strategy*. Cambridge University Press.

Appendices

A Solving the Optimization Problem of Shipping Firms

If all the IC constraints of the initial problem hold, then the whole set of IR constraints can be reduced to the following constraint:

$$\pi(\varphi^*) \geq 0, \quad \text{(IR')} \tag{50}$$

where φ^* is the entry cutoff productivity. Because $\frac{\partial \pi(\omega)}{\partial \varphi} > 0$, the downward IC constraints automatically mean the IR constraint hold for any other types higher than the lowest one.

The single-crossing condition is satisfied, as shown below:

$$\frac{\partial}{\partial \varphi}\left[-\frac{\partial \pi / \partial q}{\partial \pi / \partial T}\right] = \frac{\partial}{\partial \varphi}\left[p(\varphi) - \tau \frac{w}{\varphi} + p'q\right] > 0. \tag{51}$$

Then all the IC constraints are reduced to following two sets of constraints: the Monotonicity

$$\frac{\mathrm{d}q(\varphi)}{\mathrm{d}\varphi} \geq 0, \tag{52}$$

Local incentive compatibility

$$\left[p(\varphi) - \tau\frac{w}{\varphi} + p'q\right]\frac{\mathrm{d}q(\varphi)}{\mathrm{d}\varphi} = T'(\varphi) \quad \forall\varphi \in [\varphi^*, \infty). \tag{53}$$

Define the following function as $W(\varphi)$:

$$W(\varphi) := p(\varphi)q(\varphi) - \tau\frac{w}{\varphi}q(\varphi) - T(\varphi) = \max_{\hat{\omega}} p(\hat{\omega})q(\hat{\omega}) - \tau\frac{w}{\varphi}q(\hat{\omega}) - T(\hat{\omega}). \tag{54}$$

By the envelop theorem,

$$\frac{\mathrm{d}W(\varphi)}{\mathrm{d}\varphi} = \frac{\tau w q(\varphi)}{\varphi^2}. \tag{55}$$

Integrate the expression (55) over $[\varphi^*, \varphi]$ yields the following:

$$W(\varphi) = \int_{\varphi^*}^{\varphi}\frac{\tau w q(x)}{x^2}\,\mathrm{d}x + W(\varphi^*) = \int_{\varphi^*}^{\varphi}\frac{\tau w q(x)}{x^2}\,\mathrm{d}x. \tag{56}$$

The second equal sign is valid because the IR' constraint must hold with equality, otherwise the shipping companies can be better off by increasing $T(\omega)$. Substitute the expression of $W(\varphi)$ back into the original objective function of the shipping firms and perform an integration by parts will yield expression (8).

B The Determination of Cutoff Manufacturers

Equation (18) shows that the shipping companies have the option to maximize profits over the fixed component C of transport charges. The adjustment of C changes the productivity level of cutoff manufacturers φ^*. Therefore, this section of the appendix is to show that the shipping firms' optimization over C is the same as opimization over φ^*.

One can easily show that equation (18) holds regardless of whether $q(\varphi^*) = 0$ is exogenously imposed beforehand. In case the cutoff productivity of the manufacturers is endogenously determined, equation (18) has the following form:

$$T(q;C) = \frac{q\left[\alpha - \eta Q_j^c - \frac{\gamma}{L}q + \theta w v\right]}{\theta+1} + C = \frac{(p+\theta w v)q}{\theta+1} + C. \tag{57}$$

Substituting equation (57) back into equation (7) yields the following:

$$\max_C \int_{\varphi^*(C)}^{\infty} \frac{J_i}{N_{ij}} \left(T(q, C) - wvq(\varphi)\right) \mathrm{d}G(\varphi), \tag{58}$$

where φ^* is implicitly defined as a function of C through the following equation:

$$p(\varphi^*)q(\varphi^*) - \frac{\tau_{ij}w_i}{\varphi^*}q(\varphi^*) - T(q, C) = 0. \tag{59}$$

Using the General Leibniz rule, the first order condition of above objective function w.r.t C gives the following:

$$\underbrace{-\left[T(q(\varphi^*), C) - wvq(\varphi^*)\right] g(\varphi^*)\frac{\mathrm{d}\varphi^*}{\mathrm{d}C}}_{\text{marginal loss}} + \underbrace{\int_{\varphi^*}^{\infty} \mathrm{d}G(\varphi)}_{\text{inframarginal gain}} = 0, \tag{60}$$

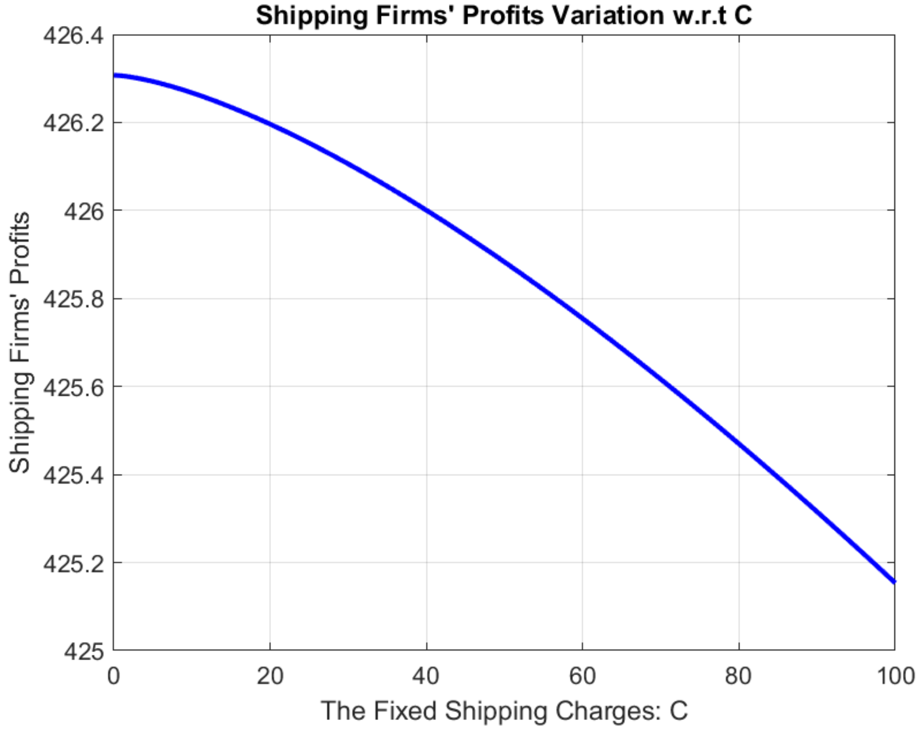
where the first underbrace shows how much profits lose from marginal unit increase in C, while the second underbrace shows how much profits gain from the inframarginal manufacturers by one unit increase of C. Essentially, this first order condition shows that the shipping firms face a trade-off when setting how much C they should charge. After dividing both sides of equation (60) by $\frac{\mathrm{d}\varphi^*}{\mathrm{d}C}$ and substituting for $\frac{\mathrm{d}C}{\mathrm{d}\varphi^*}$ with the expression generated through the total differentiation equation (59), the above first order condition arrives at equation (12).

Figure 1 is a numeric example showing how the shipping firms' profits vary with respect to the changes in the fixed component of the shipping charges C. The parameter values are given with proper discretion.[7]

The profits of the shipping firms reach their highest when the fixed component of the shipping charges vanishes to zero, which justifies the result in equation (13).

[7] The parameter values are set as follows: $L = 1$, $\tau = 1.2$, $w = 1$, $v = 2$, $\gamma = 4$, $\theta = 5$, $\alpha = 1000$, $\eta = 3$, $Q_j^c = 5$, $b = 0.001$. The range of C is [0, 100]. Here the value of Q_j^c is exogenously given, though it should be determined within the model. When the shipping firms are making decision, however, they treat Q_j^c as exogenously given. The assignment of exogenous values to Q_j^c here does not change the shipping firms' decision on their customer base.

Figure 1: Shipping Firms' Profits Variation with respect to C



C Solving the Benchmark Model

Supposing manufacturers do not use the shipping services to distribute domestically, then the marginal cost of production is $\frac{w}{\varphi} + wv$. The profits maximization yields the following conditions:

$$
\begin{aligned}
p'q + p &= \frac{w}{\varphi} + wv \\
-\left(\alpha - p - \eta Q_j^c\right) + p &= \frac{w}{\varphi} + wv \\
p(\varphi) &= \frac{1}{2}\left(\alpha - \eta Q_j^c + \frac{w}{\varphi} + wv\right) \\
q(\varphi) &= \frac{L_j}{2\gamma}\left(\alpha - \eta Q_j^c - \frac{w}{\varphi} - wv\right).
\end{aligned}
$$

If the mass of potential manufacturers ex ante in country i is denoted by J_i, then the mass of entrants M_{ij} can be expressed as follows:

$$
M_{ij} = J_i(1 - G_i(\varphi_{ij}^*)), \tag{61}
$$

where $G_i(\varphi) = 1 - \left(\frac{b_i}{\varphi}\right)^\theta$ is assumed to be the Pareto distribution where the potential manufacturers draw productivity and we assume b_i is low enough to ensure a cutoff threshold for every destination country j is active, namely $\varphi_{ij}^* > b_i$. It is straight forward to show $F_i(\varphi)$ and $G_i(\varphi)$ have the following relation:

$$F_i(\varphi) = \frac{G_i(\varphi) - G_i(\varphi^*)}{1 - G_i(\varphi^*)}. \tag{62}$$

The aggregate variable P_j is expressed as:

$$\begin{aligned}
P_j &= \int_{\omega \in \Omega_{ij}} p(\omega)\,\mathrm{d}\omega \\
&= \int_{\varphi_{jj}^*}^{\infty} J_j p(\varphi)\,\mathrm{d}G_j(\varphi) \\
&= J_j \int_{\varphi_{jj}^*}^{\infty} \frac{1}{2}\left(\alpha - \eta Q_j^c + \frac{w}{\varphi} + wv\right)\theta \frac{b_j^\theta}{\varphi^{\theta+1}}\,\mathrm{d}\varphi \\
&= J_j \frac{b_j^\theta w(1 + 2\theta + 2(\theta+1)v\varphi_{jj}^*)}{2(\theta+1)(\varphi_{jj}^*)^{\theta+1}}.
\end{aligned}$$

The profits formula is given as follows:

$$\begin{aligned}
\pi_{jj}(\varphi) &= pq - \frac{w}{\varphi}q - wvq \\
&= \frac{1}{2}\left(\alpha - \eta Q_j^c - \frac{w}{\varphi} - wv\right) q \\
&= \frac{L_j}{4\gamma}\left(\alpha - \eta Q_j^c - \frac{w}{\varphi} - wv\right)^2
\end{aligned}$$

The expected profits are given as follows:

$$\begin{aligned}
\pi_j &= \int_{\varphi_{jj}^*}^{\infty} \pi_{jj}(\varphi)\,\mathrm{d}G_j(\varphi) \\
&= \int_{\varphi_{jj}^*}^{\infty} \frac{L_j}{4\gamma}\left(\alpha - \eta Q_j^c - \frac{w}{\varphi} - wv\right)^2 \theta \frac{b_j^\theta}{\varphi^{\theta+1}}\,\mathrm{d}\varphi \\
&= \frac{b_j^\theta L_j w^2}{2\gamma(\theta+1)(\theta+2)(\varphi_{jj}^*)^{\theta+2}}.
\end{aligned}$$

The free-entry condition implies the following:

$$\begin{aligned} \pi_j &= wf_e \\ \varphi_{jj}^D &= \left[\frac{b_j^\theta L_j w}{2\gamma(\theta+1)(\theta+2)f_e}\right]^{\frac{1}{\theta+2}} \end{aligned} \tag{63}$$

which is the same productivity cutoff as in Melitz and Ottaviano (2008). Similarly, the productivity cutoff in the open economy in this paper is the same as in Melitz and Ottaviano (2008). The active mass of firms is given as follows:

$$M_j^D = \frac{2\gamma(\theta+1)(\alpha\varphi_{jj}^* - vw\varphi_{jj}^* - w)}{w\eta}. \tag{64}$$

Correspondingly, σ_p^2 is given as:

$$\begin{aligned} \sigma_p^2 &:= \int_{\varphi_{ii}^*}^{\infty} (p(\varphi) - \bar{p}_i)^2 \, \mathrm{d}F_i(\varphi) \\ &= \int_{\varphi_{ii}^*}^{\infty} \left[\frac{1}{2}\left(\alpha - \eta Q_j^c + \frac{w}{\varphi} + wv\right) - \frac{w(1+2\theta+2(\theta+1)v\varphi_{ii}^*)}{2(\theta+1)\varphi_{ii}^*}\right]^2 \mathrm{d}F_i(\varphi) \\ &= \int_{\varphi_{ii}^*}^{\infty} \left[\frac{1}{2}\left(\alpha - \eta Q_j^c + \frac{w}{\varphi} + wv\right) - \frac{w(1+2\theta+2(\theta+1)v\varphi_{ii}^*)}{2(\theta+1)\varphi_{ii}^*}\right]^2 \theta\frac{(\varphi_{ii}^*)^\theta}{\varphi^{\theta+1}} \, \mathrm{d}\varphi \\ &= \frac{w^2\theta}{4(\theta+1)^2(\theta+2)(\varphi_{ii}^*)^2}. \end{aligned}$$

The welfare expression is then given as follows:

$$U^D = 1 + \frac{1}{2\eta}\left(\alpha - v - \frac{1}{\varphi_{ii}^*}\right)\left(\alpha - v - \frac{\theta+1}{(\theta+2)\varphi_{ii}^*}\right). \tag{65}$$

D Proof of Proposition 3

To compare the following two cutoffs:

$$(\varphi_{ii}^*)^{\theta+2} = \frac{\theta}{\theta+1}\frac{\lambda L_i\left(\tau_{ij}^\theta\tau_{ji}^\theta - \left(\frac{\theta}{\theta+1}\right)^{2\theta+2}\right)}{\tau_{ji}^\theta(\tau_{ij}^\theta - \left(\frac{\theta}{\theta+1}\right)^{\theta+1})}, \; (\varphi_{ii}^{DO})^{\theta+2} = \frac{\theta}{\theta+1}\frac{\lambda L_i(\tau_{ij}^\theta\tau_{ji}^\theta - 1)}{\tau_{ji}^\theta(\tau_{ij}^\theta - 1)} \tag{66}$$

it is equivalent to assessing whether the following function is increasing or decreasing in the range of $[\theta/(\theta+1), 1]$:

$$f(x) = \frac{\tau_{ij}^{\theta}\tau_{ji}^{\theta} - x^2}{\tau_{ij}^{\theta} - x}.$$

Its derivative is:

$$f'(x) = \frac{x^2 - 2x\tau_{ij}^{\theta} + \tau_{ij}^{\theta}\tau_{ji}^{\theta}}{(\tau_{ij}^{\theta} - x)^2}.$$

A sufficient condition for the numerator of the above to be positive is to have $\tau_{ji} \geq \tau_{ij}$ and for it to be negative is to have $\tau_{ji} \ll \tau_{ij}$, at the same time θ is large enough to ensure:

$$\frac{\theta}{\theta+1} > \tau_{ij}^{\theta} - \sqrt{(\tau_{ij}^{\theta})^2 - \tau_{ij}^{\theta}\tau_{ji}^{\theta}} \quad \text{and} \quad 1 - 2\tau_{ij}^{\theta} + \tau_{ij}^{\theta}\tau_{ji}^{\theta} < 0.$$

E Solving the Full Model

The model can be solved following the steps in the benchmark model. The aggregate variable P_j is expressed as:

$$\begin{aligned} P_j &= \sum_i J_i \int_{\varphi_{ij}^*}^{\infty} \frac{1}{2}\left(p_j^* + \frac{\tau_{ij}w}{\theta\varphi} + \frac{\tau_{ij}w}{\varphi} + wv\right)\theta\frac{b_i^{\theta}}{\varphi^{\theta+1}}\mathrm{d}\varphi \\ &= \sum_i J_i \frac{b_i^{\theta}w(\tau_{ij} + 2\theta\tau_{ij} + 2\theta v\varphi_{ij}^*)}{2\theta(\varphi_{ij}^*)^{\theta+1}}. \end{aligned} \tag{67}$$

Given the quantity and payment menu $(q(\omega), T(\omega))$ specified in section 3, the profits of the manufacturers in country i earned in country j is given by:

$$\pi_{ij}(\varphi) = \frac{\theta}{\theta+1}\frac{L_j}{4\gamma}(p_j^* - \frac{\tau w}{\theta\varphi} - \frac{\tau w}{\varphi} - wv)^2 \tag{68}$$

Then, the expected profits for the manufacturers in country i is given as:

$$\begin{aligned} \pi_i &= \sum_j \int_{\varphi_{ij}^*}^{\infty} \frac{\theta}{\theta+1}\frac{L_j}{4\gamma}(p_{ij}^* - \frac{\tau w}{\theta\varphi} - \frac{\tau w}{\varphi} - wv)^2\theta\frac{b_i^{\theta}}{\varphi^{\theta+1}}\,\mathrm{d}\varphi \\ &= \sum_j \frac{b_i^{\theta}L_j\tau_{ij}^2 w^2}{(4\gamma\theta + 2\gamma\theta^2)(\varphi_{ij}^*)^{\theta+2}}. \end{aligned} \tag{69}$$

The free-entry condition implies that the productivity cutoff under a closed economy:

$$\varphi_{ii}^* = \left[\frac{L_i b_i^\theta}{2\theta(\theta+2)\gamma f_e}\right]^{1/(\theta+2)}.$$

To generate the formula of the masses of active firms, we utilize equation (14) to express Q_i^c as a function of entry cutoff:

$$Q_i^c = \frac{\alpha\theta\varphi_{ii}^* - vw\theta\varphi_{ii}^* - w\tau - w\theta\tau}{\eta\theta\varphi_{ii}^*}. \tag{70}$$

The macro variable P_i under the closed economy is given by equation (67):

$$P_i = \frac{M_i w(\tau + 2\theta\tau + 2v\theta\varphi_{ii}^*)}{2\theta\varphi_{ii}^*}.$$

Substituting the expressions of Q_i^c and P_i into the equation (4), we can arrive at the expression for the mass of active firms:

$$M_i = \frac{2\gamma(\alpha\theta\varphi_{ii}^* - \theta - 1 - v\theta\varphi_{ii}^*)}{\eta}. \tag{71}$$

$\bar{p}_i$ is given as:

$$\bar{p}_i \coloneqq \frac{P_i}{M_i} = \frac{\tau + 2\theta\tau}{2\theta\varphi_{ii}^*} + v.$$

σ_p^2 is given as:

$$\begin{aligned}\sigma_p^2 &\coloneqq \int_{\varphi_{ii}^*}^{\infty} (p(\varphi) - \bar{p}_i)^2 \, \mathrm{d}F_i(\varphi) \\ &= \frac{w^2\tau^2}{4\theta(\theta+2)(\varphi_{ii}^*)^2}.\end{aligned}$$

Because all the profits accrued in the shipping industry are rebated to consumers as wages, wage is the only source of income for each individual. Therefore, the indirect utility function under a closed economy could be expressed as the parameter values and the entry cutoff φ_{ii}^*:

$$U = 1 + \frac{1}{2}\left(\eta + \frac{\gamma}{M_i}\right)^{-1}(\alpha - \bar{p}_i)^2 + \frac{1}{2}\frac{M_i}{\gamma}\sigma_p^2$$
$$= 1 + \frac{1}{2\eta}\left(\alpha - \upsilon - \frac{\theta+1}{\theta\varphi_{ii}^*}\right)\left(\alpha - \upsilon - \frac{(\theta+1)^2}{\theta(\theta+2)\varphi_{ii}^*}\right).$$

Consider a two-country open economy where the unit shipping costs are the same both domestically and internationally. Equation (14) yields the connection between φ_{ij}^* and φ_{jj}^*:

$$\varphi_{ij}^* = \tau_{ij}\varphi_{jj}^* \quad \forall i, j. \tag{72}$$

The free entry condition of both countries implies:

$$\begin{aligned} \frac{L_j\tau_{ij}^2}{(\varphi_{ij}^*)^{\theta+2}} + \frac{L_i}{(\varphi_{ii}^*)^{\theta+2}} &= \frac{1}{\lambda}, \\ \frac{L_i\tau_{ji}^2}{(\varphi_{ji}^*)^{\theta+2}} + \frac{L_j}{(\varphi_{jj}^*)^{\theta+2}} &= \frac{1}{\lambda}. \end{aligned} \tag{73}$$

Together with equation (72), the cutoffs are given as:

$$\varphi_{ii}^* = \left(\frac{\lambda L_i(\tau_{ij}^\theta\tau_{ji}^\theta - 1)}{\tau_{ji}^\theta(\tau_{ij}^\theta - 1)}\right)^{\frac{1}{\theta+2}}, \tag{74}$$

$$\varphi_{ji}^* = \left(\frac{\lambda L_i\tau_{ji}^2(\tau_{ij}^\theta\tau_{ji}^\theta - 1)}{\tau_{ij}^\theta - 1}\right)^{\frac{1}{\theta+2}}. \tag{75}$$

As in the benchmark model, it is straightforward to verify that in any destination country i the price distribution facing the consumers is the same for goods from any source countries, which indicates that the expression for macro variable P_i is the same as in a closed economy. Equation (14) shows that the formula for macro variable Q_i^c should be the same as in the closed economy in equation (70). Thereafter, every macro variable in the open economy inherits the same formula as in the closed economy, including the welfare expression.

The mass of firms in country i consists of firms coming from domestic and foreign markets which gives the following:

$$
\begin{aligned}
M_{ji} + M_{ii} &= M_i, \\
(1 - G(\varphi^*_{ji}))J_j + (1 - G(\varphi^*_{ii}))J_i &= M_i. \qquad (76)
\end{aligned}
$$

The equations (76) and (72) can solve J_i as functions of cutoffs:

$$
\begin{aligned}
J_i &= \frac{1}{b^\theta(\tau^\theta_{ij}\tau^\theta_{ji} - 1)}(M_i(\varphi^*_{ii})^\theta \tau^\theta_{ij}\tau^\theta_{ji} - M_j(\varphi^*_{jj})^\theta \tau^\theta_{ij}) \\
&= \frac{2\gamma}{\eta b^\theta(\tau^\theta_{ij}\tau^\theta_{ji} - 1)}[(\alpha\theta\varphi^*_{ii} - \theta - 1 - v\theta\varphi^*_{ii})(\varphi^*_{ii})^\theta \tau^\theta_{ij}\tau^\theta_{ji} \\
&- (\alpha\theta\varphi^*_{jj} - \theta - 1 - v\theta\varphi^*_{jj})(\varphi^*_{jj})^\theta \tau^\theta_{ij}].
\end{aligned}
$$

The value of M_{ij} and M_{ii} can be easily derived, after knowing J_i, and correspondingly, the equilibrium number of the shipping firms on each route can be pinned down by the free-entry condition as in the closed economy.

Just as in traditional heterogeneous firms trade literature, opening to a costly trade features selection of the more productive firms into export market, $J_i > 0$ implies:

$$
\begin{gathered}
(\alpha\theta\varphi^*_{ii} - \theta - 1 - v\theta\varphi^*_{ii})(\varphi^*_{ji})^\theta > (\alpha\theta\varphi^*_{jj} - \theta - 1 - v\theta\varphi^*_{jj})(\varphi^*_{jj})^\theta \\
\frac{(\alpha\theta\frac{\varphi^*_{ji}}{\tau_{ji}} - \theta - 1 - v\theta\frac{\varphi^*_{ji}}{\tau_{ji}})(\varphi^*_{ji})^\theta}{(\alpha\theta\varphi^*_{jj} - \theta - 1 - v\theta\varphi^*_{jj})(\varphi^*_{jj})^\theta} > 1 \\
\varphi^*_{ji} > \varphi^*_{jj}.
\end{gathered}
$$

F Unequal Unit Cost of Shipping

When the unit cost of domestic shipping does not equal to international shipping, equation (14) implies a variant of equation (72):

$$
\varphi^*_{ij} = \tau_{ij}\varphi^*_{jj} + A_{ij} \quad \forall i, j. \qquad (77)
$$

where $A_{ij} = \frac{\theta}{\theta+1}(v_{ij} - v_{jj})\varphi^*_{ij}\varphi^*_{jj} > 0$.

Total differentiate equations (73) and (77) and consider a perturbation around $v_{ij} = v_{jj}\ \forall i, j$ yielding the following:

$$\underbrace{L_j \tau_{ij}^2 [-(\theta+2)](\varphi_{ij}^*)^{-(\theta+3)}}_{B_{11}} (\tau_{ij} \mathrm{d}\varphi_{jj} + \mathrm{d}A_{ij}) + \underbrace{L_i [-(\theta+2)](\varphi_{ii}^*)^{-(\theta+3)}}_{B_{12}} \mathrm{d}\varphi_{ii} = 0 \tag{78}$$

$$\underbrace{L_i \tau_{ji}^2 [-(\theta+2)](\varphi_{ji}^*)^{-(\theta+3)}}_{B_{21}} (\tau_{ji} \mathrm{d}\varphi_{ii} + \mathrm{d}A_{ji}) + \underbrace{L_j [-(\theta+2)](\varphi_{jj}^*)^{-(\theta+3)}}_{B_{22}} \mathrm{d}\varphi_{jj} = 0 \tag{79}$$

Using Cramer's rule, we arrive at the following:

$$\frac{\mathrm{d}\varphi_{jj}}{\mathrm{d}A_{ij}} = \frac{-B_{11}B_{21}\tau_{ji}}{B_{11}\tau_{ij}B_{21}\tau_{ji} - B_{22}B_{12}} > 0$$
$$\frac{\mathrm{d}\varphi_{ii}}{\mathrm{d}A_{ji}} = \frac{-B_{11}B_{21}\tau_{ij}}{B_{11}\tau_{ij}B_{21}\tau_{ji} - B_{22}B_{12}} > 0$$
$$\frac{\mathrm{d}\varphi_{jj}}{\mathrm{d}A_{ji}} = \frac{B_{12}B_{21}}{B_{11}\tau_{ij}B_{21}\tau_{ji} - B_{22}B_{12}} < 0$$
$$\frac{\mathrm{d}\varphi_{ii}}{\mathrm{d}A_{ij}} = \frac{B_{11}B_{22}}{B_{11}\tau_{ij}B_{21}\tau_{ji} - B_{22}B_{12}} < 0$$

The first two equations have some interesting implications—the increasing trade barrier will increase the destination's productivity cutoff, contradicting the intuition that the increasing trade barrier will shield domestic firms from foreign competition. The intuition behind this is indeed somewhat sophisticated. When v_{ij} goes up, a smaller fraction of manufacturers export ($\mathrm{d}\varphi_{ij}/\mathrm{d}A_{ij} > 0$), thereby lowering the expect profits, which leads to a smaller number of potential entrants. This allows for more unproductive manufacturers to survive ($\mathrm{d}\varphi_{ii}/\mathrm{d}A_{ij} > 0$), at the same time attracting more manufacturers from country j ($\mathrm{d}\varphi_{ji}/\mathrm{d}A_{ij} > 0$). The resulting expected high profits encourage more manufacturers to enter, thereby crippling the survivability of the existing ones ($\mathrm{d}\varphi_{jj}/\mathrm{d}A_{ij} > 0$).

How the cutoff level φ_{ii}^* will change depends on the level of change $\mathrm{d}A_{ij}$ and $\mathrm{d}A_{ji}$, as well as L_j, L_i, τ_{ij} and τ_{ji}. What can be asserted here is that the inclusion of a unit cost of shipping from nonlinear pricing does change the welfare evaluation.