HIAS-E-123

Price Discrimination in the Transport Industry and the Gains from Trade

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October 2022

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October 12, 2022

Abstract

Shipping companies often charges nonlinear and discriminatory pricing for transportation. This paper shows that this nonlinear and discriminatory pricing in the shipping industry could hamper the welfare gains from trade due to within-industry allocation across heterogeneous firms. I extend a standard heterogeneous firm trade model with variable markups by incorporating monopolistically competitive shipping companies that charge nonlinear and discriminatory pricing against manufacturers. In a standard setting, shipping companies optimally charge a higher transport price to the more productive firms, weakening within-industry reallocation toward productive firms. Elimination of this discriminatory practice could potentially increase the gains from trade.

Keywords: Price discrimination, Shipping industry, Heterogeneous firms, The gains from trade

JEL Codes: F12, L91, R13, R41

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1 Introduction

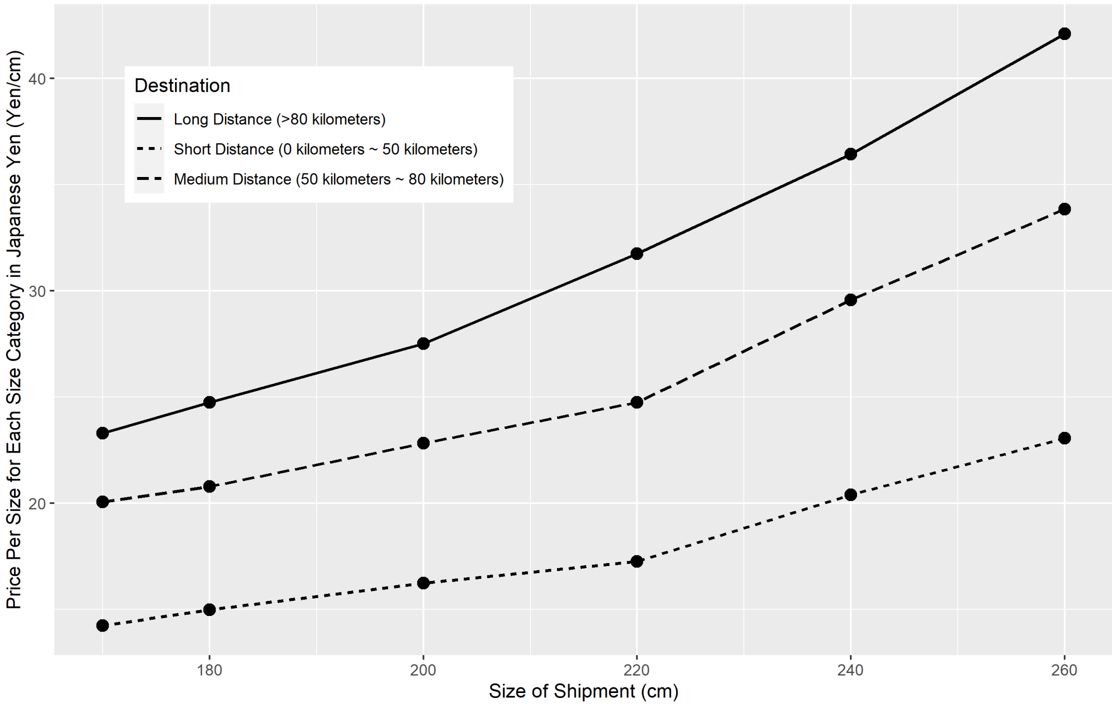
Very often trade literature has regarded freight rates and tariff rates as independent and holistic components of the iceberg trade cost. Though, because of the prevalence of non-discriminative ad valorem tariff, it is generally appropriate to envision tariff rates as a multiplicative price shifter, as it is indeed a percentage charge non-discriminatively on well-defined tariff lines, the freight rate as an uniform multiplicative price shifter actually and crucially depends on the assumption that the transport industry is perfectly competitive, which is at odds with many preceding studies showing that considerable market power resides in the transport industry, (see, *e.g.* Borenstein and Rose (1994), and Gerardi and Shapiro (2009)).

In fact, very often nonlinear pricing schedule is observed daily in life. Using price quote data from Sagawa Express Co.,Ltd, Figure 1 shows the per size price variation for the maximum $50kg$ category.[1] Conditional on the weight, the per size price is clearly increasing in the total size of the shipment regardless how far the destinations are, meaning the more bigger shipped, the higher shipping rate is. A more rigorous regression is conducted to reveal how shipments' characteristics correlate with the variation in price, which is summarized in Table 1 in the appendix. In a nutshell, it shows that shipping price increases disproportionately faster as the size of the shipment increases, hinting that shipping companies tend to charge higher per unit price the bigger the shipment is, which will be the empirical regularity this theoretical framework strives to align.

Despite this discussion about market power in the shipping industry in industrial organizations literature and evidence in real life, it is only very recently that trade economists started to document and analyze its implications in global trade flow (see, *e.g.* Hummels

[1]Data comes from the official website of Sagawa Express Co.,Ltd: https://www.sagawa-exp.co.jp/english/price/regular04.html#ft01, which lists rates for any 13 bilateral region blocks in Japan. Sagawa Express Co.,Ltd is one of the largest logistic companies in Japan. Its businesses encompass both corporate shipping and individual consumer shipping. And this price list used in this paper is for both corporate and individual customers. There might be other ways for big corporate customers using shipping service provided by Sagawa, such as signing long-term contracts. Nevertheless, given that 85.62% of enterprises in Japan have employees less than 10 according to 2016 Economic Census for Business Activity(https://www.stat.go.jp/english/data/e-census/2012/index.html#e2016), chances are high that the price quote this paper is using is the most standard and popular way of shipping inside Japan, especially among small and medium enterprises.

Figure 1: Convexity of Price Schedule across Different Distances in Japan



Note: The price displayed here is for shipments starting from Kanto area to other areas. The price per size is calculated only for the maximum $50kg$ category, as typically the price varies by both size and weight. Size refers to the summation of the length of its three dimensions of an object and it is in centimeter(cm) unit.

(2007), Hummels et al. (2009), Kleinert and Spies (2011), Ishikawa and Tarui (2018), Brancaccio et al. (2020), Ignatenko (2020), Asturias (2020), and Ardelean and Lugovskyy (2020)). However, none of the above discusses the market power phenomenon in the transport industry within the heterogeneous firm framework which accumulated empirical evidence has proven to be true and has become a starting point in international trade. This paper strives to fill the gap and shows that this nonlinear and discriminatory pricing in the shipping industry could hamper the welfare gains from trade due to within-industry allocation across heterogeneous firms.

I extend a standard heterogeneous firm trade model with variable markups by incorporating monopolistically competitive shipping companies that charge nonlinear and discriminatory pricing against manufactures. In a standard setting, shipping companies optimally charge a higher transport price to the more productive firms, weakening within-industry reallocation toward productive firms.[2] Intuitively, the more productive

[2]This result echos what Yoshida (2000) finds in a vertically-linked industry structure, where the

manufacturing firms' innate productivity advantage is sabotaged by the higher transport prices charged to them. As a result, those productive firms would not be capable of expanding as well as they otherwise would do under uniform transport fees, leaving enough space for the less productive firms to survive. Therefore, the within-industry reallocation toward productive firms conducive to higher gains from trade is dampened. Elimination of this discriminatory practice could potentially increase the gains from trade.

This paper relates to multiple strands of literature. First, it connects with studies discussing the welfare implications of trade. For a large class of mostly used trade models, Arkolakis et al. (2012) (thereafter ACR) provide an unified framework claiming that despite a wide range of settings in the trade literature, two empirical statistics are sufficient for welfare implications: (i) the share of expenditure on domestic goods; and (ii) the trade elasticity, implying that in terms of the total size of gains from trade, new trade models yield the same result as the old one. However, Melitz and Redding (2015) argue that the ACR's results are sensitive to firm productivity distribution in the sense that even an truncated version of Pareto distribution would introduce additional elements into the ACR formula and the routine application 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 where the variable trade cost is high. Similar results are also uncovered by Head and Mayer (2014)—a departure of firm heterogeneity from 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 a translog preference, Novy (2013) also finds that the trade elasticity is a variable. Therefore, Melitz and Redding (2015), together with the others, discover the varying trade elasticity without which the canonical trade literature might underestimate the gains from trade. Considering the multi-product firms setting, Bernard et al. (2011) suggest that the within firm reallocation could have comparable impact on the gains from trade as the across firm reallocation does. Additionally, Caliendo and Parro (2015) derive analytical expressions for gains from trade in

upstream firms will charge a higher unit price to the more productive downstream firms.

a world with mutisectors and vertical linkages, showing that the gains from trade would be underestimated without. Based on the roundabout model developed by Caliendo and Parro (2015), Antràs and Gortari (2020) show that the evaluation of the gains from trade differs even doubles for certain countries, when the property of sequential production stages in the value chain is incorporated. In line with the aforementioned literature, this paper strives to discover another channel hampering the gains from trade or its quantification, which the trade literature might overlook. This paper offers a possible channel, hampering the endogenous selection of firms into both domestic and export markets, which is touted by Melitz and Redding (2015) as the extra margin of adjustment leading to higher gains from trade, apart from the ones in homogeneous firms model by Krugman (1980).

This paper also contributes to literature documenting and analyzing market powers in the transport industry. Both Borenstein and Rose (1994) and Gerardi and Shapiro (2009) use a reduced-form approach to show there are considerable market powers in the airline industry. Several other studies, such as Busse and Keohane (2007), Hughes (2011), MacDonald (2013), and Hughes and Lange (2020) particularly document the market power phenomenon in domestic railroad shipping and estimate its impact on the power generating industry. Despite its vastness, none of the aforementioned studies investigates the impact of market power in the transport industry on international trade. One notable exception is Hummels et al. (2009) who estimate how the freight rate of maritime shipping responds to the goods price, tariff rate, and demand elasticity. However, the homogeneous firms setting in Hummels et al. (2009) precludes some interesting results which will be uncovered in this paper with a heterogeneous firm setting.

The next section specifies the primitives and environment needed to set up the model, followed by a list of the results inherited from Melitz and Ottaviano (2008) as the closed economy benchmark. Section 3 discusses the properties of an open economy when a discriminatory pricing scheme in the freight rate is implemented. Section 4 presents the results when an uniform pricing scheme is applied, reflecting the conventional assumption that heterogeneous manufacturers face the uniform freight rate in cross-border trade.

Section 5 compares the results under two different pricing regimes and yield the implication of the market power in the transport industry on the gains from trade. The final section concludes.

2 Primitives

The configuration follows the pathway of Melitz and Ottaviano (2008) (thereafter MO) and inherits their notations whenever possible.[3] In order to isolate the effect of the transport industry's price on the firms' decisions in the manufacture industry, the price charged by the transport industry is abstracted to be the only component of the trade cost $\tau(\omega)$, where the ω indexed trade cost hints that the transport industry is capable of charging differentiated prices. The game played by both the transport industry and the Melitz industry is delineated as follows:

In stage (i), the productivity of firms is realized and observed by the transport industry.[4]

In stage (ii), the transport industry charges a price deemed as an iceberg type $\tau(\omega)$ to each firm willing to export.

In stage (iii), taking the price charged as the trade cost, correspondingly firms produce and export.

The subsection 2.1 to subsection 2.3 enumerate and remind the pivotal structure and results in MO model upon which the later analysis will be built. Meanwhile those subsections introduce the notation convention used throughout this paper. The last subsection describes the structure imposed on the transport industry. To streamline the logic flows and at the same time keep the analysis as concise as possible, only important expressions and equations will be kept in the main text, the rest will be delegated to the theory appendix.

[3]The CES type demand function will preclude the possibility of a heterogeneous transport cost because of its property of constant mark-up pricing. Despite its popularity in the quantification analysis, the CES demand system falls short to capture the variable mark-up aspect of the reality which has been documented by numerous industrial organization literatures.

[4]Though in reality shipping firms typically cannot observe the exact productivity of their customers, they could classify their customers into several productivity categories based on past history, because of their local monopolistic power. This model provided here approximates this situation.

2.1 Preferences

The representative consumer in each country has the utility type developed by Ottaviano et al. (2002):

$$U = q_0^c + \alpha \int_{i\in\Omega} q_i^c \,\mathrm{d}i - \frac{1}{2}\gamma \int_{i\in\Omega} (q_i^c)^2 \,\mathrm{d}i - \frac{1}{2}\eta \left(\int_{i\in\Omega} q_i^c \,\mathrm{d}i \right)^2 .$$

Then the inverse demand for each variety i is given as:

$$p_i = \alpha - \gamma q_i^c - \eta Q^c, \tag{1}$$

indicating the maximum price for any variety to have a non-negative demand is:

$$p_D \coloneqq \alpha - \eta Q^c.$$

2.2 Production

Following the terminology in MO, c_D is used to denote the cost cut-off which is the marginal cost of the manufacturer with zero demand. The profit maximizing behavior of manufacturers implies the manufacturers in a country with population size L will necessarily satisfy:

$$q(c^c) = \frac{L}{\gamma}(p(c^c) - c^c), \tag{2}$$

meaning the least productive manufacturers active in the market with zero demand will effectively set its price equal to its marginal cost: $p_D = c_D$.

It is worthwhile noting that c^c represents the effective marginal cost when consumers receive the goods. Under the scenario of a closed economy and costless trade where an international shipping service is not used, $c^c = c$ the cost facing the consumer equals its cost of production. In the case of costly trading discussed in the paper, $c^c = \tau(c)c$ to account for the iceberg type transport cost.

The specification of production technology also follows MO and the distribution of c

is repeated here as:

$$G(c) = \left(\frac{c}{c_M}\right)^k, \quad c \in [0, c_M]. \tag{3}$$

2.3 Closed Economy

The closed economy as the benchmark in this paper is the same as the one in the original MO model. Some preponderant results in the MO model will be listed below to facilitate a comparison with analysis later on. Given the parametrization of cost distribution, the free-entry condition yields the cutoff cost level under the closed economy as MO:

$$c_D = \left[\frac{2(k+1)(k+2)c_M^k \gamma f_E}{L}\right]^{1/(2+k)}, \tag{4}$$

where f_E is the cost of entry.

The indirect utility function, regardless of the parametrization of cost distribution, is given as follows:

$$U = I + \frac{1}{2}\left(\eta + \frac{\gamma}{N}\right)^{-1} (\alpha - \bar{p})^2 + \frac{N}{2\gamma}\sigma_p^2, \tag{5}$$

where N is the number of active manufacturers in a particular economy. $\bar{p}$ is defined as $\bar{p} := 1/N \int_\Omega p(\omega)\,\mathrm{d}\omega$, namely the average price in that particular economy. σ_p^2 is defined as $\sigma_p^2 := 1/N \int_\Omega (p(\omega) - \bar{p})^2\,\mathrm{d}\omega$, which can be intuitively interpreted as the variance of the available price in that particular economy. All the general equilibrium objects N, $\bar{p}$, σ_p^2 can be solved as functions of c_D. The indirect utility function can then be transformed as:

$$U = 1 + \frac{(\alpha - c_D)\left(\alpha - \frac{k+1}{k+2}c_D\right)}{2\eta}. \tag{6}$$

Notice that the utility level is decreasing at c_D, confirming the intuition that the lower c_D, meaning higher market-wise average productivity is conducive to a higher welfare level. MO show that when countries are open to trade, the only sufficient statistics c_D becomes lower, implying a higher level of average productivity, which is also touted as the new margin of gains from trade by Melitz (2003).

2.4 Trade Cost and the Transport Industry

To align the model structure as close to reality as possible, a Krugman type monopolistic competition industry structure is employed in the transport industry where the transport firms' profits are rebated to consumers in terms of wages. Additionally, to highlight the consequence of the market power in the transport industry, the matching process between transport firms and manufacturers is simplified as random matching, thereby the distribution of manufacturers that each transport company is facing is the same. The market power enables transport firms to charge discriminatory prices to any firms in the manufacture industry. Those firms do not have any bargaining power when negotiating with the monopoly and simply take those prices as given, which, to some extent, can be justified by the commonly accepted infinitesimal firm setting in the monopolistic competition model.

3 Discriminatory Pricing

The analysis now moves from enumerating the results in MO as the closed economy benchmark in this paper to an open economy where exporters have to use shipping services offered by the monopolistic competitive shipping industries.

3.1 Discriminatory Pricing Schedule

Under discriminatory pricing, to be consistent with the iceberg trade cost formulation, the profit maximization problem facing a representative shipping company is formulated as:[5]

$$\max_{\tau(\cdot)} \Pi(\tau(\cdot)) = \int_0^{c_X} (\tau(\cdot)cq(c^c) - cq(c^c))\, N_s \,\mathrm{d}\left(\frac{G(c)}{G(c_X)}\right), \tag{7}$$

where N_s is the number of customers of this shipping company and c_X is the unit cost export cutoff. From the perspective of manufacturers, $\tau(\cdot)cq(c^c)$ is the total variable cost incurred from exporting and $cq(c^c)$ is the total variable production cost from exporting.

[5]To obviate from unnecessary complications and yield stark contrast to the MO model, the unit cost of shipping is assumed to be zero. Because of the monopolistic competitive nature of shipping industry, each individual shipping firm takes c_X and N_s as macro variables, which it takes as given.

The difference between these two cost terms yields the payment as well as the profits received by the shipping company, given the assumption that unit cost of shipping is zero. Summing across the profits received from different manufacturers indexed by their unit cost of production c with its corresponding measures $N_s \mathrm{d}\left(G(c)/G(c_X)\right)$ yields the total profits received by a typical shipping company. Using the technique in calculus of variation, the profit maximizing function τ must satisfy the following condition, which, in light of (7), is given by:

$$\frac{c^k k N_s L \left(c + c_D - 2c\tau(c)\right)}{2\gamma c_X^k} = 0,$$

which implies the following pricing rule:

$$\tau(c) = \frac{c_D}{2c} + \frac{1}{2}. \tag{8}$$

Notice that $c_D \geq c$ for all exporters guarantees that $\tau(c) \geq 1$ and $\tau(c)$ is a decreasing function in c, implying that the more productive manufacturers will be charged with higher transportation fees. $\tau(c)$ reaches its lower bound value, when $c = c_X$.

Lemma 1 *The discriminatory pricing schedule exercised by shipping firms is given as:*

$$\tau(c) = \frac{c_D}{2c} + \frac{1}{2},$$

implying that the more productive manufacturers will be charged higher freight rates and this pricing schedule is independent of k.

The above lemma is somewhat surprising in the way that the discriminatory pricing schedule is independent from the dispersion of the distribution of manufacturers. It seems that knowing the distribution of its customers does not procure additional gains to the shipping firms. In fact, this essentially comes from the independence of decision making facing each heterogeneous manufacturers—the freight rate charged on manufacturers with productivity c_1 will not affect the profitability of manufacturers with productivity c_2, a property intrinsic to an infinitesimal manufacturers assumption. Though the calculus of variation allows finding an optimal path with the interdependence across individuals, under the current setting, each manufacturer is independent from each other. To a typical shipping firm, the one optimal path finding problem is equivalent to the infinite static optimization problems facing each manufacturer with different productivity levels which then are added up together. In fact, one can check that the solution to the profits maximization problem is even invariant to any specification of the unit cost distribution $G(c)$.

A second noteworthy point regarding the above lemma is that the lower unit cost manufacturers are coupled with a higher unit freight rate, effectively rendering the cost c^c facing consumers an average of unit cost of production c and unit cost cutoff c_D. This theoretical result mirrors the real life situation discussed in the introduction—the more productive manufacturers tend to send more and larger shipments, therefore they are more likely facing higher unit freight rate imposed by shipping firms with market power. The higher freight rate offered to the more productive manufacturers effectively alters the distribution of c^c, perceived by the consumers and sabotages the competitive edge of the more productive manufacturers, hinting at an alternative welfare evaluation.

3.2 Cutoff Condition and Free Entry Condition

To maintain a parsimonious difference from the original MO model, and illustrate the idea in a simplified way, from here onward, a symmetric and two-country setting is assumed.[6] Given the pricing schedule as in equation (8), for a particular country i, the domestic firm with productivity c_D^i will earn zero profits as the foreign firm with productivity c_X^j, meaning the domestic productivity cutoff c_D^i and the foreign export cutoff c_X^j are connected in the following way similar to the one in original MO model:

$$c_D^i = \tau(c_X^j)c_X^j. \tag{9}$$

[6] In fact, this symmetry assumption is not a restrictive assumption at all. In the MO model, the primary asymmetry comes from the exogenous asymmetric iceberg trade cost. However, under this paper's setting where iceberg trade cost is abstracted to contain only freight rate, the freight rate is endogenously determined to be symmetric across countries. And it is irresponsive to other asymmetry assumed in MO model such as the population size.

The symmetric country assumption and the freight rate pricing schedule in equation (8) transforms the above equation into the following relationship:

$$c_D = c_X. \tag{10}$$

Equation (10) indicates that all the manufacturers who are active domestically will export, meaning the freight rate charged to the highest unit cost manufacturers is effectively zero. Therefore, according to equation (8) all manufacturers active in domestic market will export. Under the current setting where the freight rate is the only component of the iceberg trade cost and zero unit cost of shipping, there is no endogenous selection into the export market.[7] A natural result follows in equation (10)—the mass of active manufacturers in any country contains the operating manufacturers of all the origins:

$$N_T = 2N, \tag{11}$$

where N_T is the total mass of manufacturers active in a particular country and N is the mass of active manufacturers from one particular country.

The free entry condition requires that the expected profit is zero:

$$\frac{L}{4\gamma}\int_0^{c_D}(c_D - c)^2\,\mathrm{d}G(c) + \frac{L}{4\gamma}\int_0^{c_X}(c_X - \tau(c)c)^2\,\mathrm{d}G(c) = f_E \tag{12}$$

which together with equation (10) determine the cost cut-off c_D given as:

$$c_D = \left[\frac{8(k+1)(k+2)\gamma(c_M)^k f_E}{5L}\right]^{1/(k+2)}. \tag{13}$$

It is interesting to compare the cutoff level above with the one in equation (4) under a closed economy, because under this particular scenario the endogenous selection into the export market is shut. A simple comparison reveals that the domestic unit cost cut-off level is lower, indicating potential gains from higher average productivity. Though

[7]Relaxing any of the assumptions would not change the direction of pricing schedule, which complicates the comparison without providing additional insights, because both discriminatory pricing and uniform pricing are equally affected by those settings.

this result might look counter intuitive at first sight, it is very natural because endogenous selection into the domestic market is still operative—the relatively productive firms, though handicapped by the increasing freight rate, gain from accessing the foreign market thereby crowd out the least productive firms in the domestic market.

3.3 Welfare under Discriminatory Pricing

As in the original MO model, the domestic unit cost cutoff is the only sufficient statistic for the welfare, meaning all the other macro variables including N_T, $\bar{p}$, and σ_p^2 can be expressed as functions c_D whose derivations are relegated to the appendix.

Because the welfare formula in equation (5) is general to both a closed and an open economy, to whatever the unit cost distribution specification is, the welfare expression under the discriminatory pricing is given as follows:

$$U^d = 1 + \frac{\left(\alpha - c_D^d\right)\left(\left(6k+12\right)\alpha - \left(6k+7\right)c_D^d\right)}{12\left(k+2\right)\eta}, \tag{14}$$

where c_D^d denotes the domestic unit cost cutoff given as in equation (13). Similar to the closed economy benchmark, the domestic unit cost cutoff is the single sufficient statistic to the welfare level. The property that welfare is decreasing in c_D^d remains, though the formula itself is very different from the one in the closed economy benchmark.

4 Uniform Pricing

The basic setup is the same as the one under discriminatory pricing, except that the only difference is the shipping firms in the transport industry are confined to imposing an uniform price on the manufacturers, reflecting the conventional uniform freight rate assumption in trade literature.

4.1 Uniform Pricing Schedule

The profit maximization problem of a typical shipping firm, under this scheme, is formulated as

$$\max_{\tau} \Pi(\tau) = \int_0^{c_X} (\tau - 1)\, cq(c^c) N_s \,\mathrm{d}\left(\frac{G(c)}{G(c_X)}\right), \tag{15}$$

where τ is no longer a function of c. The first order condition of the above yields the following:

$$\begin{aligned} \int_0^{c_X} \frac{c^k kNL\,(c + c_D - 2c\tau)}{2\gamma c_X^k}\,\mathrm{d}c = 0 \\ \tau = \frac{2k+3}{2k+2} = 1 + \frac{1}{2k+2}. \end{aligned} \tag{16}$$

The optimal freight rate is a constant greater than one and it is decreasing in the value of structural paramter k.

Lemma 2 *Under the uniform pricing scheme, the optimal freight rate pricing schedule is given as:*

$$\tau = 1 + \frac{1}{2k+2},$$

which is decreasing in the unit cost dispersion parameter k.

Unlike the pricing schedule in discriminatory pricing, the freight rate is a decreasing in the unit cost dispersion parameter k, because now the freight rate is applied to every exporters, rendering the freight rate decision making interdependent across individuals. The intuition behind this result is fairly intricate, as it connects to the demand elasticity those heterogeneous manufacturers are facing. As k decreases, more productive manufacturers take more mass weight out of the total manufacturers population. Meanwhile, those more productive manufacturers are facing a relatively less elastic manufacturing goods demand, meaning they have higher potential rent ready to be extracted than those less productive manufacturers. Therefore, the overall freight rate tends to be higher when more productive manufacturers are taking up higher weight out of the total population.

4.2 General Equilibrium under Uniform Pricing

As $\tau = 1 + \frac{1}{2k+2}$ is a special case in the open economy discussed in the MO model, the cutoff condition and the free entry condition are basically the same as in the MO model. The domestic unit cost cutoff is connected with the export unit cost cutoff in the following way:

$$c_D = \tau c_X.$$

The free entry condition is given as:

$$\frac{L}{4\gamma}\int_0^{c_D}(c_D - c)^2\,\mathrm{d}G(c) + \frac{L}{4\gamma}\int_0^{c_X}(\tau c_X - \tau c)^2\,\mathrm{d}G(c) = f_E.$$

Together with the symmetric country assumption, the domestic unit cost cutoff can be solved as:

$$c_D = \left[\frac{2(k+2)(k+1)\gamma(c_M)^k f_E \tau^k}{L(1+\tau^k)}\right]^{1/(k+2)}. \tag{17}$$

Because of the exact same reason mentioned in the MO model, the observed price distribution of manufacturers is the same regardless of the origins of those manufacturers, the general equilibrium objects, including N_T, $\bar{p}$, σ_p^2, have the same functional form as in the closed economy benchmark. As a result, the welfare expression is the same as in the closed economy:

$$U^u = I + \frac{1}{2\eta}\left(\alpha - c_D^u\right)\left(\alpha - \frac{k+1}{k+2}c_D^u\right). \tag{18}$$

where c_D^u is the domestic unit cost cutoff under uniform pricing, whose value is given in equation (17).

5 Uniform Pricing versus Discriminatory Pricing

Given the portraits of general equilibrium under the two different scenarios, it is straight forward to compare their domestic unit cost cutoff level, which are single sufficient statistics of welfare in both situations:

$$\left(\frac{c_D^d}{c_D^u}\right)^{k+2} = \frac{4(\tau^k + 1)}{5\tau^k} > 1, \quad \forall k \in [1, 20]. \tag{19}$$

Though k is the dispersion parameter of the unit cost of production, given the quasi-linear utility function and the wage rate are taken as the numeraire, this dispersion parameter is effectively the dispersion parameter of productivity—the number of goods produced per unit of labor. The range of k from 1 to 20 covers not only the values from the trade elasticity estimate literature, (*e.g.*, Eaton and Kortum (2002), Waugh (2010) and Simonovska and Waugh (2014)) but also the value from the firm size distribution estimate, (*e.g.*, Gabaix (2016)).

Proposition 1 *The domestic unit cost cutoff under discriminatory pricing is higher than the one under uniform pricing, for commonly accepted value of dispersion parameter k.*

The intuition behind the above proposition is that, as mentioned in previous section, the nonlinear freight rate under discriminatory pricing sabotages the innate productivity advantage of the more productive manufacturers, making them unable to expand as much as they would do under uniform pricing, leaving enough market shares for the less productive manufacturers to survive. As an illustration, at the least productive extreme, the pricing schedule specified in equation (8) permits 0 freight rate, whereas, at the other extreme, the freight rate goes to infinity when the innate productivity of manufacturers goes to infinity.

As mentioned in previous section, the comparison of the domestic unit cost cutoff under a discriminatory pricing with the counterpart under a closed economy hints that there is gains from trade from the increase in average productivity. Moreover, one can show that the mass of available goods varieties, which is assumed to be the mass of operating manufacturers, is higher when open to trade under a discriminatory pricing, whose proof is given in the theory appendix.

Corollary 1 *The mass of operating manufacturers in a particular country under discriminatory pricing is higher than the mass of operating manufacturers under the closed* *economy benchmark.*

However, what is surprising is that the gains from productivity and the gains from the available variety does not guarantee the overall gains from trade under discriminatory pricing is positive, meaning the welfare level under discriminatory pricing can be lower than the closed economy benchmark. The welfare comparison of those two situations above is very technical and depends on the relative magnitude of parameter k, α, η and γ. The countervailing force reducing welfare actually comes from the market power distortion of the shipping industry. The discriminatory pricing distorts the innate unit-cost distribution and reduces the sales of manufacturers, thereby, creates dead-weight losses.

The comparison of the open economy under uniform pricing with the closed economy benchmark is very straightforward, as the uniform pricing situation is just a special case of the open economy discussed in the MO model. Therefore, all the gains from trade forces in the MO model apply here. The distortion created by the market power in the transport industry manifests as an iceberg trade cost type cost wedge—markup pricing over the shipping firms' unit cost, but it is not strong enough to offset the gains from trade.

To compare the welfare level under two different pricing regimes, a two step approach is taken. First, assume there exist a hypothetical state where the welfare formula takes the form of uniform pricing but the domestic productivity cutoff takes the value under discriminatory pricing. We denote this hypothetical welfare level as U^{dc}. Then it is straight forward to show that:

$$U^{dc} - U^{d} = \frac{(\alpha - c_D^d)c_D^d}{12(k+2)\eta} > 0. \tag{20}$$

Then notice that the welfare formula under the uniform pricing is a decreasing function in domestic unit cost cutoff and together with the inequality of unit-cost cutoff in equation (19), it implies

$$U^{u} > U^{dc}.$$

Then it follows that:

$$U^u > U^d. \tag{21}$$

Proposition 2 *The measured gains from trade under discriminatory pricing in the shipping industry is lower than the measured gains from trade under the uniform pricing in the shipping industry.*

As before, there are multiple countervailing forces behind the above proposition. The average productivity is higher under uniform pricing, whereas the available variety is ambiguous depending on the relative magnitude of the parameters. The average price is higher under the discriminatory pricing, meaning the markup tends to be higher under the discriminatory pricing. The proof of the following corollary is omitted because its logic is exactly the same as the proof of the above proposition—by assuming a counterfactual state where the formula of average price takes the form of average price under uniform pricing but with the domestic productivity cutoff under discriminatory pricing.

Corollary 2 *The average price of the operating manufacturers in a particular country under the discriminatory pricing is higher than the average price of the operating manufacturers under the uniform pricing.*

To summarize, in terms of the gains from trade, the productivity and markup favor uniform pricing, whereas the available variety is ambiguous.

Moreover the above proposition has important implication on the vast trade literature striving to quantifies the gains from trade. It shows that imposing an uniform freight rate across heterogeneous manufacturers will bias upwards the measured gains from trade, when the shipping firms have discretion to price discriminate. Though the iceberg trade cost might be appropriate as a hands-on approach to international trade questions, persistent disregard of the shipping service provider as an industry with the market power might produce misleading quantification results. The shipping industry, as an atom when compared to the entire economy, could possibly has preponderant ramification, because every single manufacturing goods about to move across space requires shipping services.

6 Conclusion

Motivated by a nonlinear pricing example of the transport industry in the real world, this paper provides a heterogeneous firm model with the transport industry and produces pricing schedule aligning well with the empirical fact. Furthermore, it analytically shows a new channel where the gains from trade can be mismeasured, which is that if the freight rate is heterogeneous across manufacturing firms, the welfare will differ from the conventional situation where every manufacturer is assumed to face with the same freight rate. In particular, if the trade cost is higher for the more productive firms, they would not expand as they would otherwise do under the uniform freight rate assumption, leaving enough space for the less productive firms to survive, dampening the new margin of the gains from trade—firms selection into production.

One promising avenue to extend this paper is to round up the evidence to test the hypotheses or results in this paper empirically. Another fruitful way of extension is to quantify this model in numbers to show whether the gains from trade would bias upward or downwards under the alternative pricing specification and whether the price discrimination in the shipping industry affects countries heterogeneously.

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Appendices

A Theory Appendix

A.1 Production, Closed Economy Benchmark and Open Economy under Uniform Pricing

The profits maximization under the demand function of (1) gives:

$$p(c^c) = \frac{\alpha - \eta Q^c + c^c}{2},$$

which can be substituted back into equation (1) for $\alpha - \eta Q^c$ to arrive at equation (2). After replacing p_D with c_D, all the performance measures can then be written as functions of c^c and c_D only, as shown in MO:

$$\begin{aligned} p(c^c) &= \frac{1}{2}(c_D + c^c), \\ q(c^c) &= \frac{L}{2\gamma}(c_D - c^c), \\ \pi(c^c) &= \frac{L}{4\gamma}(c_D - c^c)^2. \end{aligned}$$

Given the expression for profit, the free entry condition implies ex ante the expected profits equal to entry cost:

$$\frac{L}{4\gamma}\int_0^{c_D}(c_D - c)^2 \, \mathrm{d}G(c) = f_E, \tag{22}$$

where $c^c = c$ under the closed economy. This leads to the expression of c_D under the closed economy as in equation (4).

From here onward, the mathematical derivation of general equilibrium objects applies for both the closed economy benchmark and the open economy under uniform pricing in this paper because, as mentioned in the main text the situation discussed under uniform pricing is a special case of MO open economy model. The general equilibrium objects in the open economy of MO model inherits the same structure of its closed economy version.

Summing equation (1) over the available varieties will leads to an expression connects aggregate variable Q^c and $\bar{p}$:

$$\left(\eta + \frac{\gamma}{N}\right) Q^c = \alpha - \bar{p}. \tag{23}$$

Taking the above equation (23) back to the original utility function and replacing Q^c whenever possible yields equation (5). Similarly, plugging equation (23) back to equation (1) gives the following:

$$p_i = \frac{1}{\eta N + \gamma}(\gamma\alpha + \eta N\bar{p}) - \gamma q_i^c.$$

The above expression holds for any variety i. Therefore, for the variety with zero demand, it follows that

$$c_D = \frac{1}{\eta N + \gamma}(\gamma\alpha + \eta N\bar{p}). \tag{24}$$

From the definition of $\bar{p}$, we know $\bar{p}$ is a function of c_D and N:

$$\bar{p} = \frac{2k+1}{2k+2}c_D$$

Therefore, equation (24) can be used to solve N as a function of c_D:

$$N = \frac{2(k+1)\gamma}{\eta}\frac{\alpha - c_D}{c_D}. \tag{25}$$

Then it follows that σ_p can also be expressed as a function of c_D by its definition. Finally replacing N, $\bar{p}$, and σ_p as functions of c_D, the equation (5) will be transformed to equation (6).

A.2 Equilibrium Objects under Discriminatory Pricing

Similar to the closed economy, $p(c_D) = c_D$ is also the zero demand price threshold:

$$c_D = \frac{1}{\eta N_T + \gamma}(\gamma\alpha + \eta N_T\bar{p}), \tag{26}$$

where following the definition of $\bar{p}$, it can be expressed as:

$$\bar{p} = \frac{1}{N_T}\left[\left(\int_0^{c_D} Np(c)\,\mathrm{d}G(c)\right)/G(c_D) + \left(\int_0^{c_X} Np(c^c)\,\mathrm{d}G(c)\right)/G(c_X)\right].$$

Together with equation (11) and the unit cost distribution specification, the expression of $\bar{p}$ can be reduced to the following:[8]

$$\bar{p} = \frac{(8k+5)c_D}{8(k+1)}. \tag{27}$$

Substituting equation (27) back into equation (26) yields:

$$N_T = \frac{8(k+1)(\alpha - c_D)\gamma}{3c_D\eta}.$$

Because σ_p^2 is defined similarly to $\bar{p}$, in the same vein, σ_p^2 can be expressed as:

$$\begin{aligned}\sigma_p^2 &= \left(\int_0^{c_D} \frac{1}{2}\left(p(c) - \bar{p}\right)^2\,\mathrm{d}G(c)\right)/G(c_D) + \left(\int_0^{c_X} \frac{1}{2}\left(p(c^c) - \bar{p}\right)^2\,\mathrm{d}G(c)\right)/G(c_X)\\ &= \frac{c_D^2(2+11k)}{64(1+k)^2(2+k)}.\end{aligned}$$

A.3 Proof of Corollary 1

Assuming there exist a hypothetical state where the formula of active mass of firm takes the form of the closed economy but the domestic productivity cutoff takes the value under discriminatory pricing, which is denoted as N_T^{dc} and given as:

$$N_T^{dc} = \frac{2(k+1)\gamma}{\eta}\frac{\alpha - c_D^d}{c_D^d}.$$

[8] The logic of deriving $\bar{p}$ in the open economy in MO model no longer applies here, because, as mentioned in subsection 3.2, the price distribution perceived by consumers is altered by the nonlinear discriminatory pricing schedule and the price distributions of manufacturers of different origin are now different.

It is straightforward to show that the mass of active firms under discriminatory pricing is higher than its counterpart in the hypothetical state:

$$N_T^d - N_T^{dc} = \frac{2(k+1)(\alpha - c_D^d)\gamma}{3c_D^d \eta} > 0.$$

Notice that N_T^{dc} is a decreasing function in its argument c_D^d and the domestic productivity cutoff under discriminatory pricing is lower than its counterpart in the closed economy, namely $c_D^d < c_D$. Therefore, $N_T^{dc} > N$ and then we arrive at $N_T^d > N$.

B Empirics Appendix

B.1 Regression of Shipping Prices on Shipments' Characteristics

The Table 1 shows how shipping prices vary with the shipments' characteristics.

In line with the intuition, other than the two factors (size and weight) specified in the pricing menu, the distance between origin and destination is a factor positively correlates with the price. On the contrary, GRP (Gross Regional Product) in the destination region does not weigh on the price determination, suggesting no evidence of economy of scale at regional level.[9] Though weight exhibits slightly negative correlation with price variation, the significant and greater than one coefficient of size variable indicates that price tends to be higher, the more and larger the shipments are.

[9]The inclusion of destination's GRP is inspired by Clark et al. (2004) who use country GDP to instrument bilateral trade flow to identify the possible economy of scale at country level. Confirming their prediction, the instrumented bilateral trade flow is indeed significant across their different specifications.

Table 1: Regression of Price on Its Factors

	Dependent variable:	
	Price	
	OLS	Fixed Effect
	(1)	(2)
Distance	0.128***	0.150**
	(0.009)	(0.060)
Size	2.385***	2.385***
	(0.046)	(0.046)
Weight	−0.401***	−0.401***
	(0.021)	(0.020)
Destination GRP	0.012	
	(0.010)	
Constant	−3.681***	−3.649***
	(0.256)	(0.334)
Observations	495	495
R^2	0.953	0.959
Adjusted R^2	0.953	0.955
Note:	*p<0.1; **p<0.05; ***p<0.01	

[1] Robust standard error is reported. All variables are in log.
[2] Price is in Japanese Yen. Distance is in kilometer(km) unit. Size refers to the summation of the length of its three dimensions of an object and it is in centimeter(cm) unit. Weight is in kilogram(kg) unit. GRP is in million Yen current price.