Competition and Price Discrimination in International Transportation

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COMPETITION AND PRICE DISCRIMINATION IN INTERNATIONAL TRANSPORTATION *

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Abstract

This paper documents price discrimination by transport companies, revealing their market power. Larger shipments of similar products sharing a container receive lower prices. A trade model with non-linear pricing of transportation rationalizes this with economies of scale and price discrimination, highlighting their distinct policy implications. To distinguish them, I test for the effect of competition on freight price variation specific to price discrimination. Using unexpected water level changes to instrument for competition in river transportation, I find increased competition causes steeper discounts for larger shipments. Thus, market power in transportation is less distortionary for larger firms gaining additional cost advantages.

Keywords: price discrimination; quantity discounts; transportation; competition; economies of scale; mark-ups; market power

JEL codes: F10, F12, F14, D22, D43

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1 Introduction

The transportation sector is highly concentrated. In 2022, the four largest transport companies accounted for 55% of the global market for maritime transportation (UNCTAD, 2022). This has raised concerns that transport companies can act strategically and exert market power, reducing trade and welfare (Hummels et al., 2009; Brancaccio et al., 2020; Asturias, 2020). If transport companies charge prices far above their marginal costs, it can attenuate gains from investment in transport infrastructure that are commonly estimated assuming perfect competition in transportation (Donaldson, 2018; Asturias et al., 2019; Allen and Arkolakis, 2022). Furthermore, if transport companies vary prices across firms, it can have distributional consequences. Yet, identifying market power of transportation companies is challenging in the absence of detailed freight price data and measures of their marginal costs.

In this paper, I use a uniquely detailed customs dataset from Paraguay to document price discrimination by transport companies that reveals their market power. To my knowledge, this is the first dataset that identifies shipments which share a container between common pick-up and drop-off locations.[1] Such shipments have the same physical costs of transportation, as they traveled the same distance at the same speed with the same transportation conditions (e.g. refrigeration).[2] Yet, surprisingly, the average coefficient of variation of freight prices across shipments within a container is equal to 50%. Accounting for differences in shipments' volume, care and handling costs with the shipped product type only reduces the average coefficient of variation to 40%.[3]

To explore the mechanisms and implications of freight price variation, I develop a trade model, in which transport companies can have economies of scale and vary mark-ups across firms differing in productivity. Not observing firms' productivity and hence their willingness-to-pay for transportation, a transport company offers a menu of freight payments and quantities that encourage firms

[1] I use the term "container" loosely, to denote shipments transported to customs simultaneously on the same truck, boat or plane between the same pick-up and drop-off locations.

[2] Such shipments account for 30% of imported shipments by value.

[3] Brancaccio et al. (2020) report similar freight price variation in dry bulk ocean shipping.

to reveal their willingness-to-pay. In equilibrium, more productive firms are offered lower mark-ups in a form of quantity discounts as an incentive to reveal their willingness-to-pay for transportation. Since the most productive firms are offered socially optimal quantities, this form of price discrimination is less distortionary than uniform pricing.

Testing the model's predictions, I provide evidence consistent with price discrimination in the form of quantity discounts. I estimate that, on average, a one percent increase in the shipment's weight *within a container* is associated with only a 0.44% increase in total freight payment. In line with quantity discounts, this means that larger shipments within a container are charged lower per-ton freight prices. To address reverse causality and other standard endogeneity concerns in my estimates of quantity discounts, I use fixed effects and import-demand instruments for shipment size. I also show that they are not driven by over-time variation in a container's capacity, shipment's value and density, buyer-size discounts and long-term contracts.

To distinguish between price discrimination and economies of scale, I test for the effect of competition on freight price variation. Competition can affect freight price *variation* in the presence of price discrimination, but not in the case of pure economies of scale. To causally identify this effect, I use unexpected changes in the water level in Paraguay river as an instrument for a potentially endogenous entry. When water levels unexpectedly drops, Paraguay's Naval Agency lowers the maximum permitted vessel's draft (the distance between the water line and the keel of a vessel). This limits the number of transport companies on the river for reasons unrelated to freight prices or seasonality. Using this instrumental variable identification strategy, I find competition causally reduces the freight prices of *larger* shipments *more*, increasing freight price variation. This effect is consistent with price discrimination in a form of quantity discounts but not with economies of scale which implies a uniform change of all freight prices.

While the Paraguayan dataset allows me to causally identify price discrimination in the transportation sector, one concern is the external validity of this finding. I therefore provide evidence consistent with price discrimination in transportation sectors of other countries. Using container price data from Peru, I show that maritime transporters also offer discounts to firms transporting more containers on the same vessel between the same ports. These discounts are larger on more competitive routes. This implies that quantity discounts in transportation to larger countries with more competitive transportation sectors can be much larger than those in Paraguay and Peru.

These findings reveal a new role of market power in the transportation sector that affects all goods prices. Firstly, market power endogenously amplifies exogenous differences in firm productivities. Since price discriminating transport companies charge lower prices for larger shipments, more productive firms that transport larger quantities gain an additional cost advantage. Due to lower transportation costs, firms at the 75th percentile of shipment size distribution, can charge consumers 8% lower prices resulting in 40% higher sales than those at the 25th percentile. Secondly, market power of transport companies implies unequal gains across firms from improvements in transport infrastructure. When better transport infrastructure lowers transport companies' costs, they increase their mark-ups and do not fully pass the cost reductions on to firms. Mark-ups charged to more productive firms are smaller and increase more resulting in smaller reduction of freight prices of more productive firms.

This paper contributes to several areas of research. Firstly, it contributes to the literature on endogenous transportation costs. It considers the round-trip effect (Ishikawa and Tarui, 2018; Wong, 2022), transporters' technological choices (Asturias, 2020), network and scale effects (Heiland et al., 2019; Ganapati et al., 2021), and search frictions (Brancaccio et al., 2020, 2023). Holding these mechanisms fixed, I identify price discrimination by transport companies as a source of endogenous transportation costs. Hummels et al. (2009) and Ardelean and Lugovskyy (2023) also show freight price variation consistent with price discrimination based on product characteristics and firm size, respectively. Yet, it is ambiguous whether this freight price variation is driven by price discrimination or cost variation, which their data cannot distinguish. In contrast, I identify price discrimination based on unobserved firm productivity separately from economies of scale and other sources of cost variation. This distinction is important because of the distributional implications competition has in the presence of price discrimination. It benefits firms with larger productivity more through larger reductions of their freight prices. This increases trade and welfare through reallocation of production to more productive firms.

Secondly, this paper relates to the studies of welfare gains from investments in transport infrastructure (Duranton et al., 2014; Donaldson and Hornbeck, 2016; Donaldson, 2018; Heiland et al., 2019; Allen and Arkolakis, 2022). Viewing transportation costs as an exogenous friction, they assume that the benefits of better transport infrastructure are fully accrued by final goods' consumers. In contrast, my findings suggest that in the presence of market power in transportation, transportation cost reductions are not fully passed on to consumers. How much consumers benefit from better transport infrastructure depends on firm heterogeneity: larger firms are charged lower mark-ups and experience larger pass-through of transportation costs reductions into their freight prices.

Thirdly, by treating transportation as an input, I contribute to studies of the determinants and effects of input price variation across firms. They show that more productive firms purchase inputs of higher quality at higher prices, which gives them an additional (quality) advantage in their output markets (Kugler and Verhoogen, 2012; Manova and Zhang, 2012; Bastos et al., 2018; Blaum et al., 2019). I provide evidence of at least three more mechanisms through which more productive firms get an additional (cost) advantage. They get lower input prices through economies of scale, second- and third-degree price discrimination by input sellers. This can endogenously explain large differences in firm performance (Van Reenen, 2018; Ganapati, 2021).

Finally, I contribute to the ongoing debate in the industrial organization on how competition affects the extent of price discrimination. While some studies find that seller competition increases the extent of price discrimination (Borenstein and Rose, 1994; Busse and Rysman, 2005; Seim and Viard, 2011; Boik and Takahashi, 2018; Lewis, 2021), others document precisely the opposite (Gerardi and Shapiro, 2009; Gaggero and Piga, 2011; Lin and Wang, 2015). Unlike most of these papers studying consumer goods, I answer this question in a context of an input market. I adapt classic nonlinear pricing

(Mussa and Rosen, 1978; Maskin and Riley, 1984) to a vertical market and test its implications exploiting the firm-to-firm nature of international markets.

2 Theoretical Framework

I develop a theoretical framework, to guide my empirical analysis of the determinants and implications of transportation costs as freight prices. I treat transportation as an essential input purchased by manufacturers with varying productivities from transport companies with market power. I allow transport companies to engage in price discrimination without observing manufacturers' willingness to pay for transportation. I derive testable implications of a standard non-linear pricing model from industrial organization for manufacturers in a standard international trade environment. This framework embeds other pricing strategies as special cases and allows me to compare their implications.

2.1 Technologies and market structures

Consider a standard international trade environment as in Melitz (2003). An industry is populated by a continuum of manufacturers each producing a single differentiated product variety. The only input in production is labor, inelastically supplied at wage w. Manufacturers' production technology consists of constant marginal and fixed overhead costs $F > 0$. While the fixed costs are common across all manufacturers, marginal costs vary with firm productivity φ. It is drawn from a known distribution with cumulative distribution function $G(\varphi)$ and is manufacturers' private information. When exporting, manufacturers incur exogenous multiplicative trade costs $\tau \geq 1$ (*ie.* tariffs) and purchase transportation in required quantities.

The only deviation from the standard trade model is that prices for transportation are not exogenous and not necessarily proportional to transported goods' value. They are set endogenously by a transport company that can have both market power and non-constant returns to scale. It incurs total costs $K(Q)$ when transporting Q units of goods. Hence, transport companies have constant marginal costs, economies or diseconomies of scale when $K'(Q) = 0$, $K'(Q) < 0$ or $K'(Q) > 0$, respectively. In Section 4, I allow for transport companies to also have a fixed costs component.

To highlight the role of a transport company's market power, I first assume a monopoly in the transportation sector. Additionally, I assume that a transport company does not observe manufacturers' productivities but knows their distribution $G(\varphi)$.[4] In Section 4, I relax these assumptions and allow competition and long-term contracts to affect freight prices.

In this environment, a transport company achieves maximum profits by offering a menu of freight payment – quantity combinations (*freight payment schedule*), as shown in Mussa and Rosen (1978) and Maskin and Riley (1984). The equilibrium freight payment schedule is the sub-game perfect Nash equilibrium in the following game. First, the transport company announces its freight payment schedule. Then manufacturers hire labor and purchase transportation as inputs and decide how much to sell in each market. At the end, consumers in each markets purchase and consume final goods.

2.2 Firms' problems

Let $\bar{q}(\varphi) \equiv \underset{q \geq 0}{\text{argmax}}\{[p(q) - w\tau/\varphi]\, q\}$ denote the optimal output quantity of a manufacturer with productivity φ in a market with inverse demand function $p(q)$. It is naturally strictly increasing in manufacturer's productivity φ. Under free disposal, the maximum profit of manufacturer φ with a freight payment - quantity contract (q, T) is $\pi(q, \varphi) - T$, where

$$\pi(q, \varphi) = [p(\min\{q, \bar{q}(\varphi)\}) - w\tau/\varphi] \min\{q, \bar{q}(\varphi)\} - F \tag{1}$$

This profit function has two properties important for the transport company's choice of the freight payment schedule. Firstly, it is strictly increasing and strictly concave in q for $q \in [0, \bar{q}(\varphi))$: $\frac{\partial \pi(q,\varphi)}{\partial q} \geq 0$, $\frac{\partial^2 \pi(q,\varphi)}{\partial q^2} < 0$. Sec-

[4] This assumption can be easily relaxed by allowing a transport company to observe manufacturer's characteristics, $\mathbb{X}$, imperfectly correlated with their productivity. In this case, the transport company knows the distribution of manufacturer's productivities, conditional on those characteristics, $G(\varphi | \mathbb{X})$.

ondly, manufacturers with higher productivity benefit more from an increase in transportation quantity: $\frac{\partial^2 \pi(q,\varphi)}{\partial q \partial \varphi} \geq 0$.

Knowing the distribution of manufacturers' productivities, the transport company a menu of contracts (q, T), to maximize its total *expected* profits:

$$\max_{\varphi,^*(q(\varphi),T(\varphi))} \int_{\varphi^*}^{+\infty} T(q(\varphi))g(\varphi)d\varphi - K(Q), \;\; Q \equiv \int_{\varphi^*}^{+\infty} q(\varphi)g(\varphi)d\varphi$$

subject to incentive compatibility and individual rationality constraints:

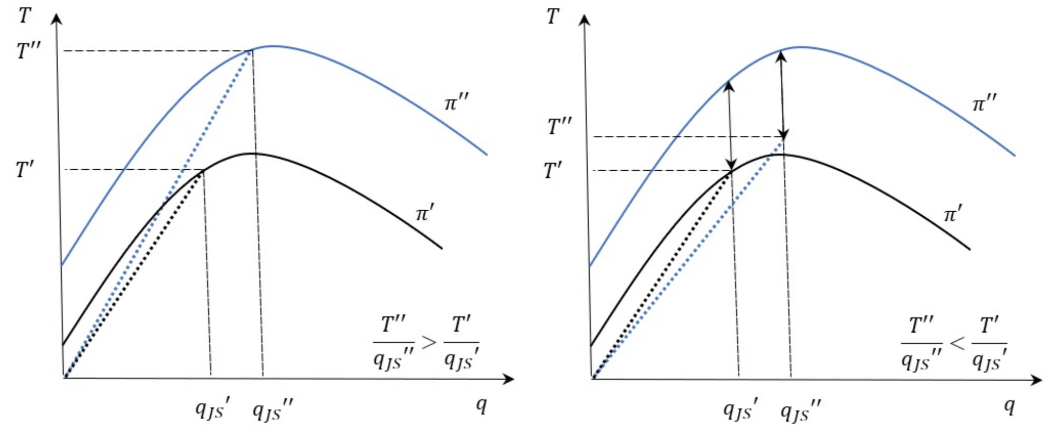
$$\forall \varphi, \varphi' : \;\; \pi(q(\varphi), \varphi) - T(q(\varphi)) \geq \pi(q(\varphi'), \varphi) - T(q(\varphi')) \qquad (IC)$$

$$\forall \varphi : \;\; \pi(q(\varphi), \varphi) - T(q(\varphi)) \geq 0 \qquad (IR)$$

These constraints are an outcome of asymetric information and transport company's inability to observe individual manufacturers' productivities. The incentive compatibility constraints (IC) ensure that each manufacturer prefers a transportation contract intended to her rather than that intended to another manufacturer. The individual rationality (IR) contraints ensure that all manufacturers receive non-negative profits after paying for transportation.

Figure 1 illustrates the role of asymetric information in the transport company's choice of freight prices, keeping its *marginal costs constant* $(K'(Q) = 0)$. It shows profit functions of two manufacturers with productivities $\phi'' > \phi'$, as well as freight payments and quantities offered to them. If the transport company knew and could distinguish manufacturers by their productivity, it would offer each of them contracts with quantities maximizing their joint surplus and payments fully extracting their profits. Figure 1a shows that, expectedly, under full information, a more productive manufacter is offered larger quantities $q''_{JS} > q''_{JS}$ for larger total freight payment, $T'' > T'$. Moreover, in equilibrium, a more productive manufacturer is offered a higher per-unit freight price, $T''/q''_{JS} > T'/q'_{JS}$, shown by the slope of the dotted line from the origin.

However, in the environment with asymmetric information, the transport company does not observe the manufacturer's productivities and cannot dis-



(a) Freight prices: full information

(b) Freight prices: asymmetric information

Figure 1. Mechanisms of freight price variation under full and asymmetric information

Notes: π'' and π' are profit functions of high and low productivity manufacturers, respectively, purchasing transportation from a monopoly transport company. q''_{JS} and q'_{JS} are joint-surplus maximizing quantities of transportation offered to two manufactures. T'' and T' are freight payments a transport company considers to charge to two manufactures. The slopes of the dotted lines from the origin are equal to per-unit freight prices, T''/q''_{JS} and T'/q'_{JS}, at joint-surplus maximizing quantities. (a) is a full information scenario, when the transport company observed manufacturer's productivities, while (b) is an asymmetric information scenario, when the transport company only knows the distribution of manufacturers' productivities.

tinguish between them. This incentivizes the more productive manufacturer to "pretend" to be a less productive one (by splitting the shipment) and take advantage of the lower per-unit freight price. Figure 1b illustrates that this strategy increases the more productive manufacturer's profits from zero to a positive value depicted with arrows. To prevent this, the transport company lowers the freight payment charged to the more productive manufacturers by this value. Figure 1b illustrates that asymmetric information in this case leads to larger quantities offered to a more productive manufacturer for larger total freight payment but lower per-unit freight price, $T''/q''_{JS} < T'/q'_{JS}$. I next derive this result formally.

2.3 Equilibrium freight price variation

The incentive compatibility and individual rationality constraints can be incorporated in the transport company's profit maximization problem as follows:

$$\max_{q,\varphi^*} \int_{\varphi^*}^{+\infty} \pi(q(\varphi),\varphi)g(\varphi)d\varphi - K(Q) - \int_{\varphi^*}^{+\infty} \frac{\partial \pi(q,\varphi)}{\partial \varphi}(1-G(\varphi))d\varphi, \quad (2)$$

where the last term represents the transfer of the transport company's profits to more productive manufacturers compatible with their incentives. The transport company first chooses quantities and then sets freight payments that extract manufacturers' profits without violating these constraints. The next proposition establishes the necessary conditions for the solution $\{\varphi^*, q(\varphi), T(\varphi)\}$.

Proposition 1. *For $\varphi \in [\varphi^*, +\infty]$, functions $q(\varphi)$ and $T(\varphi)$ solving transport company's maximization problem in (2) satisfy the following conditions:*

$$\frac{\partial \pi(q,\varphi)}{\partial q} = K'(Q) + \frac{\partial^2 \pi(q,\varphi)}{\partial \varphi \partial q}\frac{1-G(\varphi)}{g(\varphi)} \quad (3)$$

$$\frac{\partial T(q)}{\partial q} = \frac{\partial \pi(q,\varphi)}{\partial q} \quad (4)$$

If $\varphi^* \in (0, +\infty)$, it solves the following exclusion condition:

$$\pi(q(\varphi^*),\varphi^*)g(\varphi^*) - K'(Q(\varphi^*))q(\varphi^*) - \frac{(1-G(\varphi^*))}{g(\varphi^*)}\frac{\partial \pi(q(\varphi^*),\varphi^*)}{\partial \varphi} = 0 \quad (5)$$

Moreover, the least productive manufacturer φ^* served by the transport company obtains zero net profits: $\pi(q(\varphi^*),\varphi^*) = T(q(\varphi^*))$.

Proof. *See Appendix A.1.1.*

Condition (3) is the transport company's first-order condition with respect to q. The quantity offered to a manufacturer equalizes the manufacturer's marginal profit with the transport company's marginal cost plus a nonnegative distortion term. This term disappears as $\varphi \to +\infty$, which means that only the most productive manufacturer is offered the joint-profit maximizing quantity. Condition (4) is a continuous version of the incentive compatibility constraints. It states that for a chosen quantity, the transport company chooses freight payment that equalizes the manufacturer's marginal costs and benefits from transportation. Finally, condition (5) is the transport company's first-order condition with respect to productivity of the smallest manufacturer, φ^*. It trades-off extra profits from serving less productive manufacturers with losses from lowering freight prices of more productive manufacturers to ensure incentive compatibility.

Using (3) and (1) in (4) reveals two sources of marginal freight price variation - marginal costs and mark-ups:

$$\frac{\partial T(q)}{\partial q} = \underbrace{K'(Q)}_{\text{variable MC}} + \underbrace{\frac{w\tau}{\varphi^2}\frac{1-G(\varphi)}{g(\varphi)}}_{\text{variable mark-up}} \tag{6}$$

Here, mark-ups decrease in manufacturer's productivity if the inverse hazard rate function, $(1 - G(\varphi))/g(\varphi)$, decreases in φ, which is true for most distributions. Since more productive manufacturers are offered larger quantities, this means that mark-ups decrease in quantities resulting in quantity discounts. The extent of this mark-up variation depends on the degree of manufacturers' heterogeneity in productivity. If the share of highly productive manufacturers is high, $(1 - G(\varphi))/g(\varphi)$ is large, and highly productive firms buying in larger quantities get larger discounts. If they represent close to zero share of firms, they are offered smaller discounts because screening them out with large discounts is not worth the profit loss from the discounts.

Corollary. *In equilibrium, a transport company offers more productive manufacturers contracts with larger quantities, larger total freight payments, but lower mark-ups. Hence, transport contracts feature quantity discounts.*

Proof. *See above.*

Although quantity discounts in transportation do not rely on any specific functional form assumptions, the exact shape of the freight payment schedule depends on consumer preferences and distribution of firm productivities. I specify them according to a standard international trade environment and derive implications for firms participating in international trade.

2.4 Implications for a standard model of trade

In a standard international trade environment, consumer demand for variety φ is $q(\varphi) = Ap(\varphi)^{-\sigma}$, and hazard rate for the Pareto distribution of firm productivities is $g(\varphi)/(1-G(\varphi)) = \theta/\varphi$, where $\theta > \sigma - 1$. Using these functional forms in Proposition 1, the first-order conditions for the profit maximizing freight payment – quantity schedule in (3) – (5) can be re-written as:

$$\frac{\partial \pi(q,\varphi)}{\partial q} = K'(Q) + \frac{w\tau}{\varphi\theta} \tag{7}$$

$$\frac{\partial T(q)}{\partial q} = \frac{\partial \pi(q,\varphi)}{\partial q} \tag{8}$$

$$\left[A^{1/\sigma} q(\varphi^*)^{-1/\sigma} - \frac{w\tau}{\varphi^*} - K'(Q) - \frac{w\tau}{\varphi^*\theta}\right] q(\varphi^*) = F \tag{9}$$

Combining these conditions yields the following equilibrium freight payment – quantity schedule (see Appendix A.1.2):

$$T(q) = \frac{1}{\theta+1}A^{1/\sigma}q^{1-1/\sigma} + \frac{\theta}{\theta+1}K'(Q)q - \frac{1}{\theta+1}F \ \text{ for } \ q \geq \left(\frac{F\sigma}{A^{1/\sigma}}\right)^{\sigma/(\sigma-1)} \tag{10}$$

This freight payment schedule features quantity discounts that I test for in Section 4. Firstly, per-unit freight prices in (10) decrease with quantity q:

$$\frac{T(q)}{q} = \frac{1}{\theta+1}A^{1/\sigma}q^{-1/\sigma} + \frac{\theta}{\theta+1}K'(Q) - \frac{1}{\theta+1}\frac{F}{q}$$

Secondly, total freight payment elasticity with respect to quantity in (10) is less than one:

$$\frac{\partial T(q)}{\partial q}\frac{q}{T} = \frac{\frac{\sigma-1}{\sigma}A^{1/\sigma}q^{1-1/\sigma} + \theta K'(Q)q + \theta K''(Q)q^2}{A^{1/\sigma}q^{1-1/\sigma} + \theta K'(Q)q - F} < 1$$

Due to quantity discounts a one percent increase in the shipped quantity leads to a less than one percent increase in the total freight payment. This is in contrast to the Law of One Price, under which a one percent increase in quantity results in an exactly one percent increase in the total freight payment.

Importantly, quantity discounts in (10) arise from variation in transport company's mark-ups even in absence of economies of scale ($K''(Q) = 0$). They increase in the degree of firm heterogeneity captured by Pareto distribution parameter θ. When θ is small, manufacturers are more heterogeneous in their productivities with the most productive firms accounting for a larger share of their industry's output. To screen out these highly productive manufacturers with higher willingness to pay for transportation, the transport company offers steeper quantity discounts. As a result, larger firm heterogeneity (smaller θ) implies smaller total freight payment elasticity with respect to quantity.

Moreover, quantity discounts in (10) arise, even conditional on the shipment's value. To see this, rewrite the freight payment schedule in log-deviations from the freight payment for the smallest shipment q^*:

$$\log \frac{T(q)}{T(q^*)} = \frac{1}{\theta+1} \frac{p(q^*)q^*}{T(q^*)} \log \frac{p(q)q}{p(q^*)q^*} + \frac{\theta}{\theta+1} \frac{K'(Q)q^*}{T(q^*)} \log \frac{q}{q^*} \qquad (11)$$

Here, $\frac{\theta}{\theta+1}\frac{K'(Q)q^*}{T(q^*)} < 1$ is the total freight payment elasticity with respect to shipment's quantity, conditional on its value. It is positive, in contrast to the often used "iceberg" trade cost assumption, which implies zero freight payment elasticity with respect to quantity, conditional on value.

To understand how transport company's pricing decisions affect consumer prices in an importing country, derive them from condition (7) as follows

$$p(\varphi) = \underbrace{\frac{\sigma}{\sigma-1}}_{\text{mark-up}} \left(\underbrace{\frac{w\tau}{\varphi}}_{\text{production}} + \underbrace{K'(Q) + \frac{w\tau}{\varphi\theta}}_{\text{transportation}} \right) \qquad (12)$$

This expression highlights marginal freight prices as a new source of consumer price variation in an importing country, besides producer's mark-ups and marginal costs of production. It also implies that reductions in transport companies' marginal costs are not fully passed through into prices consumers pay to all but the most productive manufacturer. Consumer price elasticity with respect to the transport company's marginal costs, $K'(Q) = k$, is:

$$\frac{d\log p(\varphi)}{d\log k} = \frac{k}{\frac{\theta+1}{\theta}\frac{w\tau}{\varphi} + k} \leq 1$$

It is less than one for all product varieties except for the one produced by the most productive firm ($\varphi \rightarrow \infty$), and increases in firm productivity. Intuitively, because more productive firms are charged lower mark-ups, they adjust less leading to larger freight price increase in response to an increase in the transport company's cost.

3 Data

I use Paraguayan customs data on a universe of Paraguay's import transactions from 2013 to 2018 as a source of detailed freight price data. As an agricultural economy, Paraguay imports mainly manufactured consumer and intermediate goods such as machinery, electronics, and transportation. As a landlocked country, it imports mostly (45% of annual imports, by value) from adjacent Argentina, Brazil, and Bolivia. In absence of direct access to maritime transportation, Paraguay heavily relies on inland transportation (roads and rivers) in its imports. Depending on a transport mode, freight charges, on average, account for 9 - 15% and 13 - 20% of the imported goods value from adjacent and non-adjacent countries, respectively.

Paraguay's unique geographic location and detailed customs dataset make it particularly well-suited for studying freight prices and their implications for international trade. First, the data provides information on how goods in each import transaction were transported based on a bill of lading. It is a contract issued by a transport company to an exporter detailing firms' names, transported goods, their quantities and weight, destination, free-on-board (without freight and insurance) values and freight payments in US dollars (separately from insurance). I define a *shipment* as a collection of transactions on the same bill of lading and study freight payments across shipments.

Second, the data identifies shipments that were transported to Paraguay simultaneously on board of the same transportation vehicle following the same route between the same pick-up and drop-off locations, on the last leg of their travel. This information comes from cargo manifests submitted to Paraguay's customs by transport companies used on the last leg of travel.[5] For each trip, a transport company submits as many cargo manifests as there are stops on the way to a customs post. I define a "*container*" as a collection of shipments with the same manifest identifier, to study within-container freight payment variation. By construction, it cannot be explained by variation in costs of operating a transportation vehicle, traveled distance, speed, time, and transportation conditions (ie. refrigeration).

Third, the data reports characteristics of individual shipments, exporters and transport companies that can affect the observed freight payments. It records 8-digit Harmonizes Systems (HS) classification codes of all products in a shipment, their weight in kilograms, and value in US dollars (free-on-board, exclusive of freight and insurance payments). I track shipments' individual exporters, importers and transport companies using their company names.[6]

3.1 Summary statistics

Goods are transported to Paraguay by roads, rivers and air either directly from adjacent Argentina, Brazil and Bolivia, or from non-adjacent countries after a transshipment in Argentina, Brazil or Uruguay. Exporters from both adjacent and non-adjacent countries predominantly (92% and 72% of shipments, respectively) use roads and rivers on the last leg of transportation to Paraguay. This last leg of transportation is very likely the only leg of transportation for shipments from adjacent countries, and it accounts for 60%-80% of the total costs of transportation from non-adjacent countries. Expectedly, river transportation is the cheapest mode used to transport the heaviest and the least expensive goods, while air transportation is the most expensive mode that carries the lightest and the most expensive goods.

[5] For shipments from adjacent Argentina, Brazil, and Bolivia, which account for about a half of Paraguay's import, the last leg of travel is highly likely to be its only leg of travel.

[6] I cleaned and standardized company names using methods of textual analysis, similar to those in Bernard et al. (2018). See Appendix A.2 for details.

Table 1. Heterogeneous shipments, exporters and transporters in Paraguay

	Mean	Median	Std. Dev.
Freight per shipment, '000 $	3	2	12
Weight per shipment, ton	30	5	400
Value per shipment, '000 $	53	19	168
# HS2 per shipment	2	1	2
# Shipments per container	2	1	4
# Exporters per container	2	1	3
# HS2 per container	3	1	4
# Shipments per transporter-year	357	109	860
Weight per transporter-year, ton	11 206	2 212	32 461
# Exporters per transporter-year	125	19	358
# Shipments per exporter-year	5	1	28
Weight per exporter-year, ton	148	3	2767
# Transporters per exporter-year	11	2	32

Shipments, exporters, and transport companies in Paraguay exhibit a large degree of heterogeneity in their observed characteristics summarized in Table 1. Annually, there are around 108 500 import shipments shipped to Paraguay by roughly 25 800 exporters using around 306 transport companies (transporters). An average import shipment weights 30 ton, contains products from two 2-digit HS categories (HS2) that are worth 53 000 US dollars and cost an exporter 3000 US dollars to transport. However, they are very different in their sizes, content, and freight payments.

Importantly, exporters often share a container when transporting their goods to Paraguay. On average, a transport company simultaneously transports two shipments from two exporters on board of the same vehicle following the same route from given pick-up to drop-off locations. Shared containers account for about 20%, 30%, and 50% of all containers by count, total annual imported weight and value, respectively. Within most shared containers (83%), exporters do not share an importer, which suggests that their transportation was likely arranged by exporters.[7]

Exporters and transport companies too substantially differ in their sizes in terms of the number of annually transported shipments and weight. An average transport company transports 357 shipments or 11 206 ton per year, which comprises about 0.3% of annually imported shipments by count and weight. However, four largest transport companies altogether account for about 20% and 25% of annually imported shipments by count and weight, respectively. These larger transport companies are likely to have market power to charge freight prices above their marginal costs. Likewise, an average exporter exports only 5 shipments and 148 ton per year, while the four largest ones export 5% and 17% of annual shipments by count and weight, respectively.

Although contracts' length is unobserved in the data, it is consistent with coexistence of long-term contracts and a spot market for transportation. In a year, on average, a transporter contracts with 125 distinct exporters, while an exporter contracts with 11 distinct transport companies. An exporter's main transport company, on average, transports around 80% and 90% of the exporter's annual shipments by count and weight, respectively. Similarly, a transport company's main exporter accounts for around 46% and 40% of the company's annual shipments by count and weight, respectively. Therefore, even if exporters have long-term contracts with their main transport companies, they also likely use spot market to find alternative transporters.

3.2 Freight payment variation across shipments

Paraguayan customs data allows me to document several novel facts on the pricing of transportation. Firstly, I find that commonly used proxies for transportation costs explain only a small share of the observed variation in freight payments. Column (1) of Table 2 shows that distance between countries, common border, common language and colonial ties explain only 17% of variation

[7]In principle, either a importer or an exporter can be in charge of arranging transportation (see Ardelean and Lugovskyy (2023)) If transportation to Paraguay was mainly arranged by importers, exporters sharing a container would have also shared an importer in charge of the transportation.

Table 2. Determinants of Freight/Ton and Freight/Value

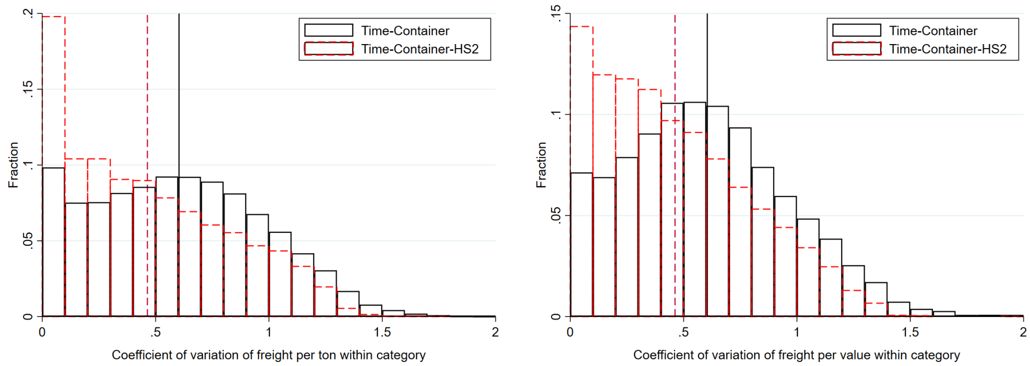
	Adj. R^2	
Dependent variable:	$Freight/Ton$	$Freight/Value$
	(1)	(2)
Distance, Border, Language, Colony, Year	0.17	0.05
Country×Year	0.27	0.07
Country×HS2×Year	0.60	0.27
Country×HS2×Mode×Year	0.78	0.33
Country×HS2×Transporter×Year	0.85	0.49

Notes: HS2 stands for a 2-digit Harmonized system's code of a product.

in per-ton freight prices across shipments. Accounting for their unobserved country-level determinants with country fixed effects explains only 27% of this variation. Additionally controlling for the type of transported goods with their HS2 code explains 60% of the observed freight-per-ton variation. Finally, accounting for a transportation mode on the last leg of travel increases the explained share of freight-per-ton variation to 78%.

Secondly, freight payment variation across shipments is not explained by variation in their values, as implied by the common "iceberg" trade cost assumption. It states that the freight per value of transported goods is constant on a given route. In contrast, column (2) of Table 2 reports that observed and unobserved country characteristics explain only 7% of variation in freight per value variation. Accounting for product type and transportation mode increases the explained portion of freight per value variation only to 33%.

Thirdly, a significant share of variation in per-ton and per-value freight prices is due to transport companies' pricing decisions unrelated to their costs. Table 2 implies that 15% and 51% of total variation remains after including transporter-country-HS2 fixed effects. To show that this variation is not driven by variation in transport companies marginal costs across shipments, I focus on shipments sharing a container on the exact same travel route at the same time. For a transport company, these shipments have identical marginal costs associated with exact traveled distance, speed, time and transportation conditions (such as refrigeration). Yet, I find economically meaningful variation



(a) Freight price variation violating the Law of One Price

(b) Freight-to-value variation violating the "iceberg" assumption

Figure 2. Large within-container variation of Freight/Ton and Freight/Value

Notes: Coefficient of variations are calculated for each category (Date-Container or Date-Container-HS2) by dividing standard deviation of freight-per-ton or freight-per-value by their means. Unit values 3 times larger and 3 times smaller than the median in each category were excluded as outliers, for illustrative purposes. Vertical lines show average coefficients across all categories.

in per-ton and per-value freight prices across shipments sharing a container.

I calculate coefficients of variation of per-ton and per-value freight prices across shipments sharing a container and plot their distributions in Figure 2. The average coefficient of variation of per-ton freight prices in Figure 2a is equal to 60%. Such large variation violates the Law of One Price, which implies zero coefficient of variation of per-ton freight prices within all containers. This freight payment variation across shipments cannot be explained by differences in shipments' value, as implied by the "iceberg" trade cost assumption. Under this assumption, freight-per-value ratios are constant and do not vary across shipments on a given route. In contrast, Figure 2b shows that the average coefficient of variation of freight-per-value ratios is also around 60%. Accounting for shipment's volume and handling costs with product-type (HS2) fixed effects only slightly reduces variation in both per-ton and per-value freight prices bringing their average coefficients of variation to just under 50%.

4 The role of price discrimination and competition in transportation

In this section, I provide evidence of price discrimination in a form of quantity discounts as a mechanism behind the documented within-container freight price variation. I test its distinct implications derived in Section 2 relative to other market-power- and cost-based pricing strategies of transport companies. This allows me to assess the relevance of the "iceberg" assumption, economies of scale, and various types of price discrimination for transportation costs.

4.1 Identification strategy

To diagnose the sources of freight price variation, I first test properties of the freight payment schedule derived in Section 2 under general consumer demand and distribution of manufacturers' productivities. According to Proposition 1 and its corollary, equilibrium total freight payments increase in the shipment size and feature quantity discounts. To test this prediction, I estimate the log-linear relationship between total freight payment and shipped quantities:

$$\log Freight_{icd}(\varphi) = \beta \log Weight_{icd}(\varphi) + \log \psi_{icd} + \varepsilon_{icd}(\varphi), \tag{13}$$

where i, c, d, and φ denote transport company, route, date, and manufacturer, respectively. The first term captures transport company's mark-up variation across shipment size, and the second term, $\log \psi_{icd}$, captures its total costs of transportation. Price discrimination (second-degree) in a form of quantity discounts implies that mark-ups decrease in shipment size: $0 < \beta < 1$.

I estimate β using shipment's gross weight (incl. packaging) as a measure of its size[8], and container fixed effects as a proxy for transport company's marginal costs. I address several standard endogeneity concerns that can bias and hinder the interpretation of the estimated coefficient as evidence of price discrimination. I use the richness of my data to account for various sources

[8] In Section 4, I account for shipment's volume with product fixed effects.

of bias in β and carry out a reduced-form test designed to isolate the role of transport companies market power behind the relationship in (13).

Addressing endogeneity. Firstly, I alleviate *simultaneity* bias driven by unobserved quality of transportation across shipments. I use container fixed effects to absorb much of variation in transportation quality due to the differences in traveled distance, speed, and general transportation conditions (such as refrigeration). I also experiment with product-type fixed effects and shipment's value as additional controls for quality of transportation within a container. Secondly, I address several sources of *omitted variable* bias driven by unobserved differences in transport company's costs across shipments within a container, such as paperwork costs and costs of capacity.

One source of the omitted variable bias in β that cannot be controlled for with observables is shipment-level economies of scale. If transport company's marginal costs decrease in shipment's size, then even without market power, transport companies could offer smaller per-ton freight prices to larger shipments. Since shipment-level economies of scale are not accounted for by container fixed effects, I design a reduced-form test that isolates transport company's market power in per-ton freight price variation.

To separate variation in transport company's mark-ups from shipment-level economies of scale, I estimate the effect of competition on per-ton freight prices across shipments of varying sizes. I expand equation (13) as follows:

$$\begin{aligned} \log Freight_{icd}(\varphi) =& \beta \log Weight_{icd}(\varphi) + \beta_n \log N_{cd} + \\ & \beta_{nq} \log N_{cd} \times \log Weight_{icd}(\varphi) + \log \psi_{icd} + \varepsilon_{icd}(\varphi) \end{aligned} \tag{14}$$

where N_{cd} denotes the number of transport companies on route c at time d. If per-ton freight price variation across shipments is entirely driven by shipment-level economies of scale, then the number of transport companies on a route should affect per-ton freight prices of all shipments equally. In other words, shipment-level economies of scale under constant mark-ups imply $\beta_{nq} = 0$. In contrast, if per-ton freight price variation is, at least partly, driven by mark-up variation, then competition can affect per-ton freight prices of shipments of different sizes differently. In other words, market power of transport companies

Table 3. Mechanisms of freight price variation

	β	β_{nq}
Price discrimination based on quantity	< 1	< 0
Price discrimination based on demand elasticity	< 1	> 0
Economies of scale	< 1	0

can result in $\beta_{nq} \neq 0$.

I show that price discriminating transport companies adjust their per-ton freight price differentially across shipments of different sizes, in response to competition. If transport companies price discriminate based on unobserved exporter characteristics, they lower their per-ton freight prices more for larger shipments (see Appendix A.1.3). This implies that $\beta_{nq} < 0$.[9] In contrast, if they price discriminate based on observed exporters' demand elasticities, they lower their per-ton freight prices more for smaller shipments (see Appendix A.1.4). This implies that $\beta_{nq} > 0$. Table 3 summarizes how estimated coefficient β_{nq} distinguishes price discrimination based on quantity from other mechanisms of freight price variation.

When estimating β_{nq}, I address a potential endogeneity of entry.[10] I exploit unexpected changes in the water level in Paraguay river to instrument for the number of transport companies in the river transportation segment. When it drops unexpectedly, the river becomes unnavigable for standard-size barges. This limits the number of transport companies and allows for a causal identification of the effect of competition on per-ton freight price variation.

4.2 Evidence of price discrimination in transportation

I first estimate the relationship between shipment's total freight payment and size in equation (13) with as simple OLS. To absorb variation in transport companies' marginal costs, I use variation in freight payments across shipments sharing a container between the same pick up and drop-off locations on the last

[9] Herweg and Müller (2013) and Boik and Takahashi (2018) derive the same effect of seller competition on the extend of (second-degree) price discrimination in other environments.

[10] Although firms are expected to endogenously enter markets with higher price levels, it is not clear whether more firms enter markets with higher price variation.

Table 4. Evidence of quantity discounts within a container

Dependent Variable:	$\log Freight_{icd}(\varphi)$			
	(1)	(2)	(3)	(4)
$\log Weight_{icd}(\varphi)$	0.517***	0.438***	0.529***	0.445***
	(0.038)	(0.028)	(0.050)	(0.031)
$\mathbb{1}_c\,[NonAdjacent]$	0.238***		0.184***	
	(0.052)		(0.047)	
$\log Weight_{icd}(\varphi) \times \mathbb{1}_c\,[NonAdjacent]$		0.094		0.103
		(0.060)		(0.065)
Constant	3.110***	3.230***	3.084***	3.135***
	(0.236)	(0.343)	(0.308)	(0.380)
Container	✓			
Container×Country		✓		
Container×HS2			✓	
Container×Country×HS2				✓
N obs	124442	88848	124442	88848
N clusters	358	350	358	350
Adj. R^2	0.880	0.920	0.907	0.932

Standard errors clustered at exporter- and transporter- levels in parentheses.
* p<0.10, ** p<0.05, *** p<0.01

Notes: Shipment is identified with its Bill of Lading. φ, i, c, and d denote exporter, transport company, route, and date of shipment. $\mathbb{1}_c\,[NonAdjacent]$ equals one for shipments *not* from Brazil, Argentina and Bolivia, and zero otherwise. Container identifies shipments transported simultaneously on board of the same vehicle following the same route on the last leg of transportation. HS2 is a 2-digit HS classification code.

leg of transportation. Because it is very likely the only leg of transportation for shipments from adjacent to Paraguay countries (Argentina, Brazil, and Bolivia), I estimate β in equation (13) separately for shipments from adjacent and non-adjacent to Paraguay countries.

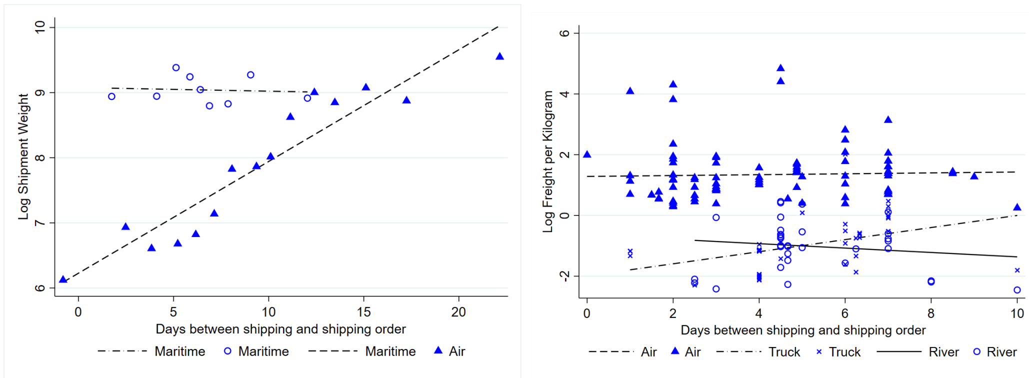
Table 4 presents my benchmark results. Column (1) shows that, across shipments sharing a container, a one percent increase in the shipment's gross weight, on average, is associated with only 0.5% increase in its freight payment. Within a container, shipments from non-adjacent countries with more than one leg of travel, are charged 24% more for transportation than shipments of the same size from adjacent countries. However, the rate at which freight payment increases with shipment size is the same across shipments from adjacent and non-adjacent countries within a container. Column (2) shows that across shipments from the *same country* within a container, a one percent increase in shipment's gross weight is associated with only a 0.44% increase in the freight payment. This estimated $\beta < 1$ in equation (13) implies that per-ton freight prices decrease in shipment's size, in line with quantity discounts.

Columns (3) and (4) of Table 4 further demonstrate that these within-container quantity discounts remain when shipment size is measured with volume rather than weight. Although shipments' volumes are unobserved in my data, their product composition is. Since products in the same HS2 product category have similar volumes per kilogram, I use shipment's weight, conditional on HS2 product category of shipped goods, to approximate its volume.[11] Column (3) implies that accounting for shipments' volumes still leaves an 18% difference in freight payments between shipments from adjacent and non-adjacent countries within the same container on the last leg of travel.[12] Moreover, column (4) shows that, within a container, shipments from the same country that are larger by volume rather than weight are also offered volume discounts. These discounts are very similar to quantity discounts in column (2). This means that they are not an outcome of transportation indivisibilities (Holmes and Singer (2018)), under which constant per-volume freight prices imply lower per-ton freight prices for more densely packed shipments.

I next argue that the estimated within-container quantity discounts are not a result of standard biases discussed in Section 4.1. Firstly, I show that they are not driven by unobserved differences in transport companies' costs not captured by container-product fixed effects. One such cost component is time-varying opportunity costs of container capacity. If larger shipments' transportation is arranged earlier, when the container is less full, they might be offered lower freight prices because of the lower opportunity costs of capacity. To rule out this mechanism, I supplement my data with information on shipping and shipping order dates available in Peru's customs data. I use the

[11] In Table A10, I use container freight prices from Peru, to show that capturing shipment's volume with its weight and HS2 fixed effects underestimates discounts based on volume.

[12] It also means that inland transportation (via adjacent countries) accounts for the bulk (82%) of transportation costs faced by Paraguay's overseas exporters.



(a) Transportation of larger shipments is not always arranged earlier

(b) Freight prices not significantly affected by advance shipping order

Figure 3. Freight payments and capacity constraints across shipment sizes

Notes: Binned scatter plots obtained from combining data on shipments exported from Peru to Paraguay from Peru's customs data with data on their freight payments from Paraguay's customs data.

number of days between between these dates to capture capacity constraints: the larger this number is, the more in advance transportation is arranged and the low are the capacity constraints.

Figure 3a shows that there is no evidence that transportation of larger shipments is arranged earlier than that of smaller ones. In fact, maritime transportation of *larger* shipments tends to be arranged slightly *later*. Figure 3b further shows that, for a given mode, freight prices do not vary with the average number of days in advance an exporter arranges transportation. As a result, accounting for container's capacity in Table A11 does not eliminate within-container quantity discounts.

Then, I show that within-container quantity discounts are not explained by differences in handling and care costs correlated with shipment value and not accounted for by product fixed effects. If transport companies' costs depend on shipments' value, omitting it would bias upwards my OLS estimates of freight price elasticity with respect to weight. Therefore, in Table 5, I additionally control for shipment's value (free-on-board, excl. freight and insurance) in a subsample of shipments from adjacent to Paraguay countries. The results in columns (1) and (2) confirm that omitting shipment's value biases the

OLS estimates of freight price elasticity with respect to weight upwards and underestimates the extent of quantity discounts. Column (2) suggests that, conditional on shipment's value, a one percent increase in shipment's size is associated with only 0.27% increase in the freight payment.

Moreover, I argue that within-container quantity discounts are not explained by unobserved customs paperwork costs. If these costs increase less than linearly with shipment size, to economize on them, transport companies might have incentives to offer discounts for transportation of larger shipments. These incentives and the average discounts would be then larger, the larger the paperwork costs are. In contrast, Figure A8 in Appendix A.3 shows that within-container quantity discounts are not sensitive to the number of hours documentary and border compliances take in an exporter's country.

To address other sources of bias including simultaneity and measurement errors, I estimate within-container quantity discounts using an instrumental variable approach. I use total weight of goods delivered to a Paraguayan importer from a foreign manufacturer by all *other* transport companies in a given quarter as a demand-side instrument for shipment's weight in a container. Column (5) of Table 5 shows that this measure of importer's quarterly demand is strongly positively correlated with a shipment size within a container. Using this instrument, in column (3) of Table 5, I still find that larger shipments of a given value from the same country within a container are charged lower per-ton freight prices.[13]

4.3 The effect of competition on freight price variation

The results presented so far suggest that transport companies increase freight payments with shipment size nonlinearly thus offering lower per-ton freight prices for transportation of larger shipments. This is consistent with price discrimination based on unobserved manufacturer's productivity, other forms of price discrimination, and economies of scale at the shipment level. To

[13] In Table A12, I obtain similar results using quarterly weight transported to an importer from manufacturers other than the manufacturer of a given shipment. Hence, shipments delivered to an importer by other transport companies are from different manufacturers.

Table 5. Evidence of quantity discounts within a container, conditional on shipment's value

Dependent Variable:		$\log Freight_{icd}(\varphi)$			
	(1)	(2)	(3)	(4)	(5)
	OLS	OLS	IV	Reduced form	First stage
$\log Weight_{icd}(\varphi)$	0.377***	0.271***	0.471***		
	(0.017)	(0.014)	(0.060)		
$\log Value_{icd}(\varphi)$		0.215***	0.038	0.453***	0.880***
		(0.015)	(0.049)	(0.017)	(0.038)
$\log Weight_{-icq}(\varphi)$				0.023***	0.048***
				(0.004)	(0.007)
Constant	3.750***	2.485***		1.938***	-1.624***
	(0.122)	(0.135)		(0.172)	(0.355)
Container×Country	✓	✓	✓	✓	✓
N obs	86162	86162	86162	86162	86162
N clusters	259	259	259	259	259
Adj. R^2	0.810	0.824	0.405	0.784	0.864
First-stage F			50.5		

Standard errors clustered at exporter- and transporter levels in parentheses.
* p<0.10, ** p<0.05, *** p<0.01

Notes: Shipment is identified with its Bill of Lading. φ, i, c, and d denote exporter, transport company, route, and date of shipment. $Weight_{-icq}(\varphi)$ is gross weight shipped by transport companies other than i to exporter φ's importer in quarter q. Container identifies shipments transported simultaneously on board of the same vehicle following the same route on the last leg of transportation.

distinguish between them, I test their differential predictions on the effect of competition of transport companies on freight price variation across shipments of varying sizes, summarized in Table 3.

I identify the effect of competition of transport companies on per-ton freight prices across shipments by estimating equation (14) in Table 6. I use the number of transport companies in a transportation segment (river, road, air) in a given month of the year as a measure of competition in transportation. Column (1) shows that, within a transporter-exporter relationship, per-ton freight prices of shipments in the same product category unsurprisingly fall when competition in the transportation sector increases. More surprisingly, column (2) shows that they fall more for larger shipments among those transported by the same transport company from the same country in the same month. This effect follows from the negative estimated coefficient on the interaction between shipment size and the number of transport companies ($\beta_{nq} < 0$ in equation (14)). It rules out economies of scale as the only source of freight price variation, which implies equal effect of competition on freight prices of *all* shipments. Yet, it is consistent with price discrimination as a mechanism of freight price variation across shipment sizes (see Section 4.1).

In columns (3)-(5) of Table 6, I address endogeneity of entry and estimate the causal effect of competition on freight price *variation* across shipments transported at the same time. I exploit unexpected weather-motivated restrictions on vessel entry in the Paraguay river to construct an instrument for the level of competition of transport companies on the river. Together with Parana, it bears about a half of the country's imports but often becomes unnavigable upstream for standard barges that requires water level of at least three meters.[14] To avoid river blockages, Paraguay's Naval Agency issues monthly decrees setting maximum permitted vessel's draft (distance between the keel and the waterline) upstream. Figure 4 shows that it often falls below three meters, which prevents transport companies with standard barges from entry and limits competition.

While relevant for entry of transport companies on the river, unexpected changes in the maximum permitted draft, are uncorrelated with the demand conditions for several reasons. First, as shown in Figure 4, these draft restrictions closely follow the water level in the river upstream, which means that their over-time variation is driven by exogenous weather conditions. Second, Figure 4 shows that the water level and the maximum permitted draft often deviate from their expected (average) levels in a given month across years. Hence, some changes in the maximum permitted draft are unexpected based on its monthly average. This makes deviations of the maximum permitted draft from its monthly average, as an instrument for the number of transport companies on the river, satisfy the exclusion restriction.

To identify the causal effect of competition on freight price *variation* across

[14] See World Bank's report: Southern Cone Inland Waterways Transportation Study

Table 6. The effect of competition of transport companies on freight prices

Dependent Variable:	$\log Freight_{icmy}(\varphi)$				
	(1)	(2)	(3)	(4)	(5)
	OLS	OLS	IV	Reduced form	First stage
$\log Weight_{icmy}(\varphi)$	0.782***	0.675***	0.673***	0.674***	-0.013
	(0.006)	(0.003)	(0.003)	(0.003)	(0.008)
$\log N_{my}$	-0.378***				
	(0.102)				
$\log \hat{W}eight_{icmy}(\varphi) \cdot \log \hat{N}_{my}$		-0.024*	-0.116**		
		(0.013)	(0.051)		
$\log \hat{W}eight_{icmy}(\varphi) \cdot \log \hat{D}_{my}$				-0.014**	0.122***
				(0.006)	(0.019)
$\log Gas\ Price_{my}$	1.342***				
	(0.268)				
$\log Currency(\varphi)/\$_{my}$	0.360**				
	(0.173)				
$\log Guarani/\$_{my}$	-0.423*				
	(0.254)				
Constant	4.183*	1.850***		1.849***	0.122*
	(2.196)	(0.028)		(0.029)	(0.074)
Transporter×Exporter×Year	✓				
Transporter×Country×Month		✓	✓	✓	✓
HS2×Month	✓	✓	✓	✓	✓
N obs	41129	98175	93668	93668	93668
N clusters	1457	1281	1196	1196	1196
Adj. R^2	0.929	0.792	0.666	0.791	0.214
First-stage F			46.8		

Standard errors clustered at the month-year-transporter level in parentheses.
* p<0.10, ** p<0.05, *** p<0.01

Notes: φ, i, c, and d denote exporter, transport company, route, and date of shipment. N_{my} and D_{my} are, respectively, the number of transport companies on the river and maximum permitted vessel's draft. $\hat{x}$ denotes x's deviation from its average in month m. HS2 is a 2-digit product code in HS classification.

shipments transported from the same country in the same month, I include transporter-country-month-year fixed effects. Although this precludes the identification of the effect of competition on freight price levels, the effect on

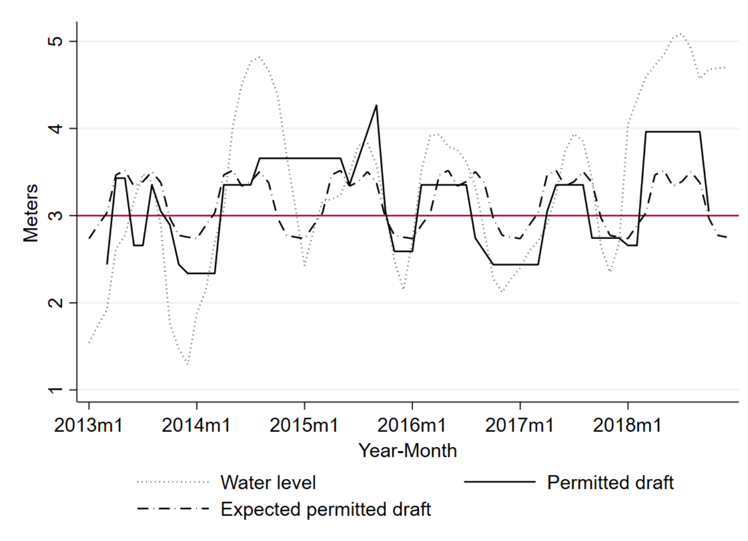


Figure 4. Maximum permitted vessel's draft in Paraguay river closely follows water level and is not fully predictable by seasonal trends

Notes: Maximum permitted vessel's draft in meters set out by Paraguay's Naval agency and water levels from La Dirección de Meteorología e Hidrología upstream of the Paraguay river from over time.

freight price *variation* across shipment sizes is still identified. To estimate this effect, I instrument for the interaction between the number of transport companies and (demeaned) exporter's weight transported with a transport company in a given month. Columns (4) and (5) of Table 6 show that, when the maximum permitted draft unexpectedly increases, transport companies lower per-ton freight prices for larger shipments more and more transport companies operate on the river. The IV estimates in column (3) further confirm that, when faced with more competition, transport companies reduce their per-ton freight price more for larger shipments. This effect is, by absolute value, larger and more significant than suggested by the OLS estimate in column (2).

The documented increase in the average quantity discounts of transport companies in response to competition is not a result of selection of heavier shipments in transportation in months with larger maximum permitted draft. I account for this selection by normalizing the exporter's monthly transported weight by the average weight transported by a transport company in that month. Figure A9 also shows that there is no selection of exporters by size and products by weight into transportation in certain months that could explain my results.[15] Instead, I show that they are driven by unexpected drops in the maximum draft below 3 meters, which make the river unnavigable for most barges in Paraguay's fleet. In Table A13, I obtain quantitatively similar results using deviations of the dummy variable for high permitted draft (more than 3 meters) from its monthly average, to instrument for the level of competition.

4.4 Alternative mechanisms of mark-up variation

The presented evidence suggests that within-container freight price variation is most consistent with mark-up rather than cost variation. I now argue that this mark-up variation is driven by price discrimination in a form of quantity discounts rather than other forms of price discrimination.

Firstly, I distinguish price discrimination in a form of quantity discounts from price discrimination based on observable exporter characteristics. If a transport company price discriminates based on the observed exporter's productivity, then lower per-ton freight prices are charged to more productive exporters that also transport in larger quantities (see Appendix A.1.4). I test this mechanism against price discrimination based on quantity discounts in Table 7. I use total annual weight transported to Paraguay by an exporter as a theoretically consistent measure of exporter productivity. In column (1), I show that overall larger and more productive exporters pay lower per-ton freight prices for shipments of the same size and content within a container.[16] Yet, accounting for this does not affect within-container quantity discounts in the baseline specification (column (4) of Table 4) in any significant way.

Secondly, I distinguish the effect of long-term contracts between exporters and transport companies on per-ton freight prices from quantity discounts. If larger shipments are transported within long-term contracts, the observed freight price variation can reflect discrimination against spot-market buyers

[15] Figure A8 demonstrates that the average quantity discounts are not explained by transport companies' fixed costs of filling customs documentation and border compliance.

[16] This is in line with the results in Ardelean and Lugovskyy (2023) who use Chilean data.

or lower transaction costs of long-term contracts. To account for this, I use total annual weight transported by an exporter with a transport company as a proxy for an unobserved long-term contract between them. In line with this alternative mechanism, column (2) of Table 7 shows that, all else equal, transport companies charge lower per-ton freight prices to exporters transporting more with them in a year. However, accounting for the existence of long-term contracts only slightly reduces the average within-container quantity discounts estimated in column (1). Alternatively, in column (3), I use exporter-transporter-year fixed effects to fully absorb differences in transportation contracts. This lowers the average within-container quantity discounts by 30% relative to the baseline estimate in column (4) of Table 4.

To estimate quantity discounts only in a spot market for transportation, I use shipments transported by transport companies that account for less than 20% of their exporters' annually exported weight. These shipments comprise about 25% of all shipments,[17] and their transportation is highly likely to be arranged on the spot market. Column (4) of Table 7 shows that the average within-container quantity discounts in this subsample are 13% smaller than in the full sample (in Table 4). This implies that long-term contracts can explain only 13% – 30% of the average within-container quantity discounts, while the rest is explained by price discrimination based on quantity.

Finally, I confirm that transport companies price discriminate across exporters rather than importers organizing transportation, as argued in Ardelean and Lugovskyy (2023).[18] For shipments from Chile, I supplement my data with information on who arranges their transportation – exporter or importer, available in Chile's customs data. I estimate the relationship between freight payment and shipment size across shipments exported from Chile to Paraguay within exporter-route, in Table A14. I find the same average quan-

[17]This is similar to the estimates of a spot market size in the US trucking and global maritime industries in Harris and Nguyen (2022) and Ardelean et al. (2022).

[18]While Ardelean and Lugovskyy (2023) report that transportation of 55% of Chilean import shipments are organized by importers, I find that it depends on firms' sizes. In Table A15, I use Peru's maritime import shipments, to show the probability transportation is exporter-organized increases in exporter size and decreases in importer size.

Table 7. Quantity discounts within a container unexplained by exporter's overall size and long-term contracts with transporters

Dependent Variable:	$\log Freight_{icd}(\varphi)$			
	(1)	(2)	(3)	(4)
$\log Weight_{icd}(\varphi)$	0.453***	0.462***	0.606***	0.516***
	(0.030)	(0.031)	(0.054)	(0.075)
$\log Weight_{icd}(\varphi) \times \mathbb{1}_c\,[NonAdjacent]$	0.099	0.098	0.046	0.073
	(0.065)	(0.064)	(0.086)	(0.090)
$\log Weight_y(\varphi)$	-0.013***			
	(0.005)			
$\log Weight_{iy}(\varphi)$		-0.026***		
		(0.008)		
Constant	3.252***	3.300***	2.181***	2.823***
	(0.403)	(0.402)	(0.558)	(0.514)
Container×HS2	✓	✓	✓	✓
Exporter×Transporter×Year			✓	✓
Contracts	All	All	All	Spot
N obs	88848	88848	59913	16371
N clusters	350	350	315	213
Adj. R^2	0.932	0.932	0.962	0.969

Standard errors clustered at exporter- and transporter- levels in parentheses.
* $p<0.10$, ** $p<0.05$, *** $p<0.01$

Notes: Shipment is identified with its Bill of Lading. φ, i, c, and d denote exporter, transport company, route, and date of shipment. $Weight_y(\varphi)$ and $Weight_y(\varphi)$ are exporter's total weight and weight transported with transport company i in year y. $\mathbb{1}_c\,[NonAdjacent]$ equals one for shipments *not* from Brazil, Argentina and Bolivia, and zero otherwise. Container identifies shipments transported simultaneously on board of the same vehicle following the same route on the last leg of travel. HS2 is a 2-digit HS classification code. "Spot" denotes shipments of transport companies that account for less than 20% of their exporters' annually exported weight.

tity discounts in a subsample of shipments whose transportation is organized by exporters (column (2)) as those in the full sample (column (1)).

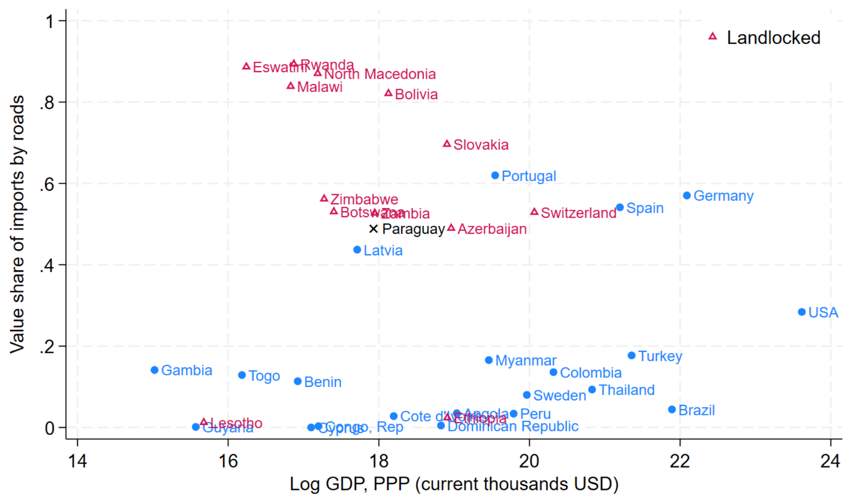


Figure 5. Roads carry a large share of imports in a wide range of countries

5 Quantitative importance of market power in international transportation

5.1 Freight price variation in world transportation

The documented evidence of price discrimination and effects of competition in the transportation sector is based on freight price data from Paraguay. A natural concern is whether transport companies delivering goods to larger countries with access to the sea also have market power to price discriminate and are affected by competition. Therefore, I compare Paraguay's transportation industry to that in other countries and present evidence from other countries with maritime transportation consistent with my findings.

One concern is that my findings are specific to Paraguay and other small landlocked economies, which heavily rely on road transportation in international trade. To address this concern, I show that roads carry a significant share of imports not only to small and landlocked countries, but also to large economies with access to the sea. I collect data on the value share of imports transported by roads across 41 countries and plot it against their logged GDP in Figure 5.[19] It shows that roads transport more than a half of imports by value to Germany, Spain and Portugal. Roads also carry 15 – 30% of imports to countries with maritime transportation as their main transport mode: the US, Turkey, and Colombia. Therefore, my findings that are mainly based on road transportation in Paraguay are relevant for a wide range of countries.

Another concern is whether freight price variation in maritime container shipping is also driven by price discrimination. This is a valid concern given that maritime transportation carries 70% of the world trade (Ardelean et al. (2022)) and is known to feature economies of scale (Asturias et al. (2019)). To address it, I construct a novel dataset on container freight prices in maritime transportation to Peru. I combine data on shipment-level freight payments from Peru's import declarations with information on the size and number of containers per shipment, vessel, transport company, and ports from Peru's maritime bills of lading. Similarly to Paraguayan customs data, this allows me to study transport company's freight price variation across shipments on board of the same vessel between the same ports at the same time.

I estimate the relationship between freight payment and shipment size in Peru's maritime transportation and present the results in Table 8. I first use gross weight as a measure of shipment's size and include exporter's annual weight exported to Peru, to account for the overall exporter size effect, as in Section 4. Column (1) shows that maritime transport companies also charge lower per-ton freight prices to larger shipments transported on board of the same vessel at the same time and on the same route. It reports that a one percent increase in the shipment's size, on average, is associated with only a 0.53% increase in its freight payment. These quantity discounts cannot be explained by most source of transport companies' cost variation and exporter's overall size. Importantly, they are of similar magnitude as those estimated using Paraguayan customs data in Table 7.

Next, I show that quantity discounts in maritime transportation are robust to using volume rather than weight, to measure shipment and exporter sizes.

[19] I combine information from UN Comtrade, US Census Bureau (Schott (2008)) and individual countries' customs data.

Table 8. Quantity discounts in maritime transportation of imports to Peru

Dependent Variable:	$\log Freight_{icd}(\varphi)$			
	(1)	(2)	(3)	(4)
	All	All	Exporter organized	Exporter organized $20Foot = 0$
$\log Weight_{icd}(\varphi)$	0.532***			
	(0.019)			
$\log Weight_y(\varphi)$	-0.049***			
	(0.008)			
$\log Containers_{icd}(\varphi)$		0.717***	0.749***	0.733***
		(0.028)	(0.035)	(0.041)
$\log Containers_{icd}(\varphi) \times 20Foot$		0.170***	0.146***	
		(0.046)	(0.046)	
$20Foot$		-0.419***	-0.399***	
		(0.025)	(0.028)	
$\log TEU_y(\varphi)$		-0.039***	-0.056***	-0.070***
		(0.006)	(0.009)	(0.014)
$\log Containers_{icd}(\varphi) \times \log \hat{N}_y$				-0.090***
				(0.028)
Constant	3.292***	7.875***	7.917***	7.866***
	(0.130)	(0.030)	(0.044)	(0.069)
Transporter-Vessel-Route-Date	✓	✓	✓	✓
N obs	8904	8904	3841	1685
N clusters	27	27	23	20
Adj. R^2	0.702	0.732	0.785	0.796

Robust standard errors clustered at the exporter and transporter levels in parentheses.
* p<0.10, ** p<0.05, *** p<0.01

Notes: Shipment is identified as a combination of transporter, exporter, date, port of departure, customs of receipt. $Weight_{icd}(\varphi)$ and $Containers_{icd}(\varphi)$, denote, respectively, gross weight (incl. packaging) and the number of containers per shipment shipped by transport company i from exporter φ at time d on route c. $Weight_y(\varphi)$ and $TEU_y(\varphi)$ are, respectively, weight and volume (in TEU) exported to Peru by exporter φ in year y. $20Foot$ is equal to one for shipments contained in only 20-foot containers, and zero otherwise.

In column (2), I use the number of 20- and 40-foot containers per shipment and the number of annually exported 20-foot container equivalent units (TEU) per exporter, as measures of shipment and exporter sizes, respectively. Firstly, I find that, although a 40-foot container is twice as big by volume as a 20-foot container, freight price for a 40-foot container is only 40% more higher. Secondly, doubling the number of containers of a given size is associated with only 70-90% increase in the total freight payment. I show that these discounts are offered to exporters, rather than importers organizing the transportation. In column (3), I restrict my sample to shipments whose transportation is organized by exporters and obtain the same quantity discounts[20].

Finally, I show that maritime transport companies in Peru respond to competition in the same way as river and road transporters in Paraguay. In Figure A10, I illustrate that more competitive routes connecting Peru with larger economies have expectedly lower freight prices per TEU. More surprisingly, in Table 8, I show that more competitive routes also feature larger quantity discounts offered by maritime transport companies to larger shipments. In column (4), I find that a one percent increase in the number of transport companies above average lowers the freight payment elasticity to the number of containers per shipment from 0.7 to 0.6.[21] This implies that in markets with more transport companies than in Peru and Paraguay, quantity discounts in transportation can be larger than those documented in this paper.

5.2 Market power in transportation and consumer prices

My findings suggest that besides increasing transportation costs faced by all producers, market power of transport companies amplifies differences in their exogenous productivities. More productive firms have a cost advantage and charge consumers lower prices not only because of lower production costs but also because of lower transportation costs. Here, I quantify the role of price discrimination on the part of transport companies in variation of firm costs, inclusive of transportation, and consumer prices.

I first assess an additional cost advantage more productive firms get by shipping in larger quantities through price discrimination in the transporta-

[20] I infer this information from incoterms, as in Ardelean and Lugovskyy (2023)

[21] This is quantitatively similar to the effect of competition found in Paraguay using an instrumental variable strategy in Table 6.

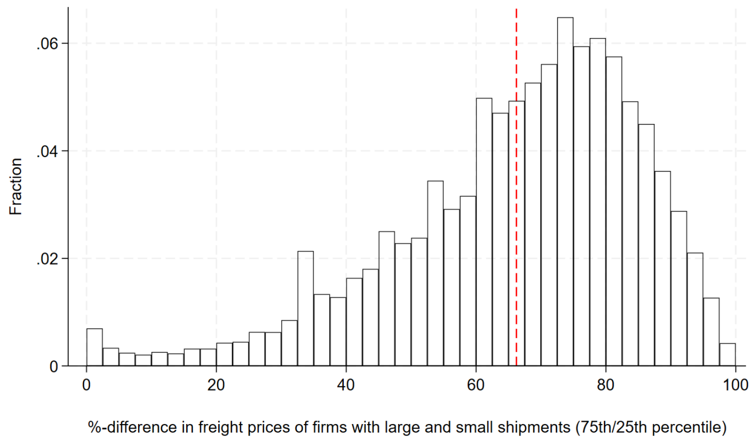


Figure 6. Additional cost advantage of firms with large shipments due to price discrimination in the transportation sector

Notes: %-differences in freight prices across firms are calculated for each HS8-product-country category. For illustrative purposes, categories with less than 10 shipments are dropped; categories with %-differences above 98 are assigned the value of 98. The vertical line shows average across all categories.

tion sector. My estimates in Section 4 suggest that, due to price discrimination, per-unit freight prices across shipments within a container decrease with shipment size with elasticity -0.56. It implies that, in a given market, firms with shipments at the 75th percentile of shipment size distribution, $q75$, face $(1-(q75/q25)^{-0.56})\times 100\%$ lower per-unit freight prices than those with shipments at the 25th percentile, $q25$. I apply this formula to $q75/q25$ ratios in each product-country category, to obtain the %-difference in freight prices between firms at the 75th and 25th percentile of the shipment size distribution.

Figure 6 plots the distribution of the %-differences in freight prices across firms in a market implied by price discrimination in the transportation sector. It shows that, on average, firms with shipments at the 75th percentile of their size distribution face 66% lower freight prices than those with shipments at the 25th percentile. How does this affect differences in their consumer prices?

To answer this question, I write consumer price as a sum of producer and per-unit freight prices, and derive its elasticity with respect to shipment size:

$$\frac{\partial p^{cif}}{\partial q}\frac{q}{p^{cif}} = \frac{\partial p^{fob}}{\partial q}\frac{q}{p^{fob}}\frac{p^{fob}}{p^{cif}} + \frac{\partial t}{\partial q}\frac{q}{t}\frac{t}{p^{cif}}, \tag{15}$$

where $p^{cif}(q)$, $p^{fob}(q)$, and $t(q)$ are consumer price, producer price, and per-unit freight price, respectively. Intuitively, when per-unit freight price decreases, it lowers consumer prices both directly and indirectly – by reducing the producer price. As a result, the consumer price elasticity with respect to shipment size is a weighted average of the elasticities of producer price and per-unit freight price with respect to shipment size. The weights are shares of producer and freight prices in the consumer price, respectively.

Therefore, the role of freight price variation in consumer price variation is mediated by the share of freight price in the consumer price. I calculate this share for each product-country category and multiply it by the estimated freight price elasticity with respect to shipment size. This yields consumer price elasticity with respect to shipment size directly driven by price discrimination in the transportation sector. I apply this elasticity to $q75/q25$ ratios in each product-country category, to obtain the %-difference in consumer prices between firms at the 75th and 25th percentile of the shipment size distribution.

Figure 7 plots the distribution of the %-difference in consumer prices across firms in a market driven by price discrimination in the transportation sector. It shows that, on average, firms with shipments at the 75th percentile of their size distribution, can charge consumers 8% lower prices relative to those at the 25th percentile. Assuming that the elasticity of substitution between varieties is equal to 5, this implies a 40% difference in firms' sales. This is a large competitive advantage that more productive firms gain directly by shipping in larger quantities. It gets even bigger if producer price variation driven by freight price variation is accounted for.[22]

[22] Estimating the producer price elasticity with respect to shipment size, $\frac{\partial p^{fob}}{\partial q}\frac{q}{p^{fob}}$ in (15) is beyond the scope of this paper. Yet, given the large share producer prices take in consumer prices (91% on average, in Paraguay), it can have a large contribution to the consumer price elasticity with respect to shipment size. Hence, assuming $\frac{\partial p^{fob}}{\partial q}\frac{q}{p^{fob}} = 0$ underestimates the role of price discrimination in the transportation sector in consumer price variation.

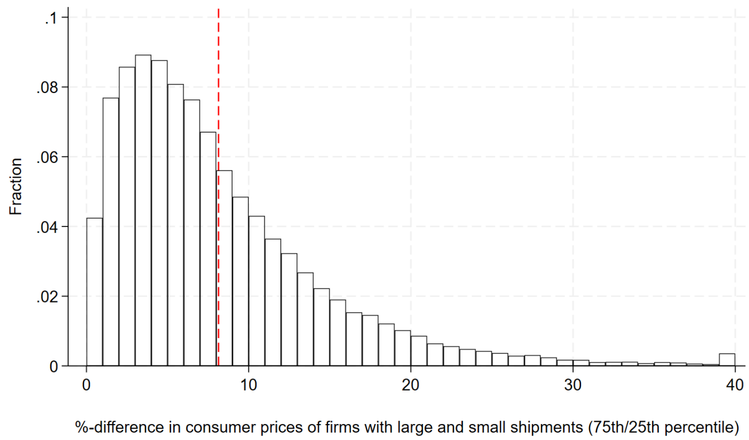


Figure 7. Consumer price variation across firms implied by price discrimination in the transportation sector

Notes: %-differences in consumer prices across firms are calculated for each HS8-product-country category. For illustrative purposes, categories with less than 10 shipments are dropped; categories with %-differences above 40 are assigned the value of 40. The vertical line shows average across all categories.

6 Conclusions

This paper documents price discrimination and strategic response to competition by transport companies that uncover their market power. It overcomes a major empirical challenge faced by previous researchers – the unavailability of freight price data and detailed measures of physical costs of transportation. Drawing this information from a uniquely detailed customs dataset, I isolate price discrimination from economies of scale in freight price variation across shipments sharing a container between their pick-up and drop-off locations. I show that both mechanisms benefit larger, more productive, firms by allowing for non-linear pricing of transportation in a standard model of trade.

Yet, economies of scale and price discrimination in transportation have very different implications for policies aimed at reducing firms' transportation costs. As one of such policies, investments in transport infrastructure can encourage entry of new transport companies and reduce marginal costs of the existing ones. My findings imply that the pass-through of these cost reductions into freight prices is incomplete and depends on the distribution of firm productivities within goods markets. Entry of new transport companies benefits initially larger, exogenously more productive, firms more through larger reduction of their freight prices. However, their freight prices decrease less following a reduction of marginal costs of the existing transport companies that adjust their mark-ups differently across firms. Accounting for these mechanisms in the estimates of gains from investments in transport infrastructure is a promising avenue for future research.

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A Online Appendix

A.1 Theory

A.1.1 Proof of Proposition 1

To simplify transport company's objective function, first, re-write it as follows:

$$\max_{\varphi^*,T(\varphi),q(\varphi)} \int_{\varphi^*}^{+\infty} \pi(q(\varphi),\varphi))g(\varphi)d\varphi - K(Q) - \int_{\varphi^*}^{+\infty} V(\varphi)g(\varphi)d\varphi,$$

where $V(\varphi) \equiv \pi(q(\varphi),\varphi) - T(q(\varphi))$. Integrating the last term by parts obtains

$$\int_{\varphi^*}^{+\infty} V(\varphi)g(\varphi)d\varphi = V(\varphi)(G(\varphi)-1)\Big|_{\varphi^*}^{+\infty} - \int_{\varphi^*}^{+\infty} V'(\varphi)(G(\varphi)-1)d\varphi.$$

The (IR) constraint for the least productive firm implies that the first term on the right-hand side is equal to zero. Now, consider the second term, and take the derivative of $V(\varphi)$ with respect to φ:

$$V'(\varphi) = \underbrace{\left(\frac{\partial \pi(q(\varphi),\varphi)}{\partial q} - \frac{\partial T(q(\varphi))}{\partial q}\right)}_{=0 \text{ by (IC) constraint}} \frac{dq}{d\varphi} + \frac{\partial \pi(q,\varphi)}{\partial \varphi} = \frac{\partial \pi(q,\varphi)}{\partial \varphi}$$

Substituting it back in the integral of $V(\varphi)$, leaves us with

$$\int_{\varphi^*}^{+\infty} V(\varphi)g(\varphi)d\varphi = -\int_{\varphi^*}^{+\infty} \frac{\partial \pi(q,\varphi)}{\partial \varphi}\left(G(\varphi)-1\right)d\varphi$$

This, in turn, leads to transport company's profit maximization problem in (2):

$$\max_{\varphi^*,q(\varphi)} \int_{\varphi^*}^{+\infty} \pi(q(\varphi),\varphi)g(\varphi)d\varphi - K(Q) - \int_{\varphi^*}^{+\infty} \frac{\partial \pi(q,\varphi)}{\partial \varphi}\left(1-G(\varphi)\right)d\varphi.$$

The first-order conditions with respect to q and φ^* yield (3) and (5) in Proposition 1, respectively. Condition (4) follows from a continuous version of the (IC) constraints, while the exclusion restriction that $\pi(q(\varphi^*), \varphi^*) = T(q(\varphi^*))$ follows from the (IR) constraint binding for the least productive manufacturer, φ^*.

A.1.2 Equilibrium freight payment schedule in a Melitz-Chaney framework

To find equilibrium freight payment schedule (10) in a Melitz-Chaney framework, first, use (7) in (8):

$$\frac{\partial T(q)}{\partial q} = \frac{\partial \pi(q, \varphi)}{\partial q} + K'(Q) + \frac{w\tau}{\varphi\theta}$$

.

Then, re-write condition (7) as

$$p'(q)q + p(q) - \frac{w\tau}{\varphi} = K'(Q) + \frac{w\tau}{\varphi\theta}$$

CES utility function implies $p'(q) = -\frac{1}{\sigma}A^{1\sigma}q^{-1/\sigma-1}$. Then condition (8) implies the following relationship between φ and q:

$$\frac{w\tau}{\varphi} = \frac{\theta}{1+\theta}\left[\frac{\sigma-1}{\sigma}A^{1/\sigma}q^{-1/\sigma} - K'(Q)\right]$$

.

Using it in the expression for $\frac{\partial T}{\partial q}$ yields:

$$\frac{\partial T}{\partial q} = K'(Q) + \frac{1}{1+\theta}\left[\frac{\sigma-1}{\sigma}A^{1\sigma}q^{-1/\sigma} - K'(Q)\right] = \frac{1}{1+\theta}\left[\frac{\sigma-1}{\sigma}A^{1\sigma}q^{-1/\sigma}\right] + \frac{\theta}{1+\theta}K'(Q)$$

.

Finally, equilibrium freight payment schedule (10) solves this differential equation given that conditions (9) are satisfied.

A.1.3 The effect of competition on quantity discounts (second-degree price discrimination)

Theoretical framework in Section 2 can be extended to feature competition, rather than a monopoly, in a transportation sector. As in Herweg and Müller (2013), a competitive fringe of transport companies leaves manufacturers with a non-zero "reservation" profits when not contracting with a transport company, $\bar{\pi}(\varphi)$. This affects the (IR) constraints, which now ensure that, when contracting with a transport company, manufacturers get at least $\bar{\pi}(\varphi)$ as their net profits:

$$\pi(q(\varphi), \varphi) - T(q(\varphi)) \geq \bar{\pi}(\varphi)$$

.

Herweg and Müller (2013) prove that quantity discounts still arise in equilibrium, when there are two buyers that are both served in equilibrium, for whom the competitive fringe is not too attractive, and $\bar{\pi}(\varphi'') \geq \bar{\pi}(\varphi')$ for $\varphi'' \geq \varphi'$.

Attanasio and Pastorino (2020) prove that quantity discounts arise in equilibrium with buyer's type-dependent outside options in a more general environment with a continuum of buyers. They show that it is characterized with the following first order condition:

$$\frac{\partial T}{\partial q} = \frac{\partial \pi(q, \varphi)}{\partial q} = K'(Q) + \frac{\gamma(\varphi) - G(\varphi)}{g(\varphi)} \frac{\partial^2 \pi(q, \varphi)}{\partial q \partial \varphi} \tag{16}$$

and a set of complementary slackness conditions on the (IR) constraints:

$$\int_{\varphi^*}^{+\infty} [\pi(q, \varphi) - \bar{\pi}(\varphi)] \, d\gamma(\varphi) = 0.$$

Here, $\gamma(\varphi) = \int_{\varphi^*}^{\varphi} d\gamma(x)$ is the cumulative multiplier associated with the IR constraints. It has the same properties as a cumulative distribution function: it is non-negative, weakly increasing, and approaches 1 when $\varphi \to +\infty$.

Using Melitz-Chaney framework's assumptions, $G(\varphi) = 1 - \varphi^{-\theta}$, $\frac{\partial^2 \pi(q,\varphi)}{\partial q \partial \varphi} =$

$\frac{w\tau}{\varphi^2}$, the first order condition in (16) can be re-written as

$$\frac{\partial T}{\partial q} = K'(Q) + \frac{w\tau}{\varphi\theta} + \frac{\gamma(\varphi) - 1}{\varphi^{1-\theta}} \frac{w\tau}{\theta} \tag{17}$$

The difference between this condition and the one derived under a monopoly assumption in Section 2 comes through the last term in (17). It is negative for all except for the most productive manufacturer, because $\gamma(\varphi) < 1$ for $\varphi < +\infty$. Hence, in a competitive environment relative to the monopoly, all manufacturers, except for the most productive one, are offered strictly larger quantities of transportation for a strictly lower marginal price. The sufficient condition for quantity discounts to arise in the equilibrium is that the last term in (17) also decreases in φ. This is the case when $\theta > 1$ and $\gamma'(\varphi)\varphi > (1 - \gamma(\varphi))(\theta - 1)$. This condition also guarantees that quantity discounts offered in a competitive environment are larger than those offered by a monopoly transport company.

Boik and Takahashi (2018) prove that competition increases the extent of quantity discounts even if competitors behave strategically rather than as a competitive fringe.

A.1.4 The effect of competition on third-degree price discrimination (based on observed characteristics)

In contrast, third-degree price discrimination implies that an increase in the number of sellers leads to a smaller reduction in mark-ups charged to more productive manufacturers than less productive ones. I show this in an environment similar to that in Hummels et al. (2009), where N symmetric transport companies $i = 1, \ldots, N$ compete in an oligopolistic transportation sector.

Under CES consumer utility as in Section 2, derived demand for transportation by manufacturer φ is

$$q(t, \varphi) = \left[\frac{\sigma}{\sigma - 1}\right]^{-\sigma} A \left(\frac{w\tau}{\varphi} + t\right)^{-\sigma} \tag{18}$$

Here, t is a constant per-unit freight price determined in an oligopolistically competitive transportation sector. When N symmetric transport companies compete in constant per-unit freight prices, they simultaneously and independently from each other choose t for manufacturer φ to maximize profits:

$$\max_{t_i} \pi_i^T = (t_i - k_i)\, Q_i(t,\varphi), \quad \sum_{i=1}^{N} Q_i(t,\varphi) = q(t,\varphi),$$

where, to focus on transport companies' mark-ups, their marginal costs, k_i, are assumed to be constant. Taking the first-order condition and then using the symmetry assumption yields:

$$t - k + \frac{\partial t}{\partial q}\frac{q}{t}\frac{t}{N} = 0 \Rightarrow t = k\frac{1}{1 + \frac{\partial t}{\partial q}\frac{q}{t}\frac{1}{N}}. \tag{19}$$

In other words, in equilibrium, per-unit freight price is a multiplicative mark-up over a transport company's marginal costs. The mark-up is higher when the inverse demand elasticity, $\frac{\partial t}{\partial q}\frac{q}{t}$ is lower, by absolute value. From (18), the inverse demand elasticity for transportation is

$$\frac{\partial t}{\partial q}\frac{q}{t} = -\frac{w\tau/\varphi + t}{\sigma t} \tag{20}$$

Its absolute value increases in manufacturer's productivity, φ. Therefore, if a transport company price discriminates based on the observed manufacturer's productivity, it charges lower prices to more productive manufacturers that also transport larger quantities.

Both price discrimination based on observed (third-degree) and unobserved (second-degree) manufacturer's productivity yield similar patterns of per-unit freight price variation. They both predict that more productive manufacturers transporting larger quantities are charged lower per-unit freight prices. However, price discrimination based on observed manufacturer's productivity predicts per-unit freight price variation across manufacturers but not across units within the same manufacturer. In contrast, price discrimination in a form of quantity discounts based on unobserved manufacturer's productivity predicts variation in per-unit freight prices even across units purchased by the same manufacturer. I use this distinction to separately identify the two types of price discrimination in Table 7.

Additionally, the two types of price discrimination yield differential predictions on the effect of competition on per-unit freight price variation. To see this, use (20) in (19) and solve for the equilibrium per-unit freight price:

$$t = \frac{\sigma k N + w\tau/\varphi}{\sigma N - 1}.$$

Expectedly, an increase in the number of transport companies, N, results in lower per-unit freight prices for all manufacturers. However, per-unit freight price elasticity with respect to the number of transport companies decreases, by absolute value, in manufacturer's productivity φ:

$$\frac{\partial t}{\partial N}\frac{N}{t} = -\frac{\sigma N(k + w\tau/\varphi)}{(\sigma N - 1)(\sigma k N + w\tau/\varphi)} = -\frac{1}{\sigma N - 1} - \frac{w\tau/\varphi}{\sigma k N + w\tau/\varphi}$$

This means that more productive manufacturers experience a smaller reduction in prices than less productive ones when the number of transport companies increases.

A.2 Data

Procedures to clean and standardize declared manufacturers' names

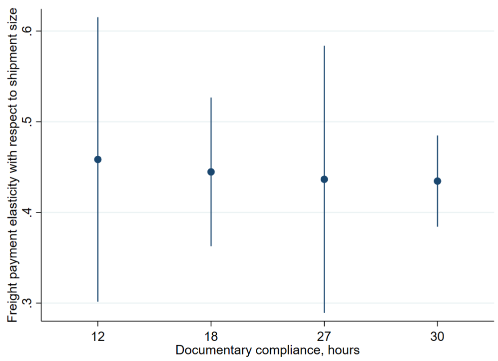
First, I cleaned declared foreign manufacturers' names from commonly used legal abbreviations (Ltd., Limited, Incorportated, LLC, GMBH, Group, Company, Holding, etc), names of their countries (reported separately in the data) and names of largest cities. I also removed word indicators of trade intermediaries (exp, imp, trading, etc.). Then, to correct spelling mistakes in manufacturers' names, I calculated a similarity score between every two cleaned company names, using Stata's *matchit* function. This similarity score ranges from 0 to 1, where a score of 1 implies a perfect similarity between two strings, according to the chosen string matching technique. I started with the strictest *token* technique, for which I used the threshold similarity score value of 0.9 to identify the two names as the same. This resulted in clusters of firms with very similar names, to which I assign a common name. Then to these common names I sequentially applied other techniques in the order of their strictness: *circular fourgram-*, *threegram-*, *fivegram-*, and *bigram-*. Each time I assigned a common name to firms with a similarity score above 0.75 and proceeded by matching the resulting names with another method. This procedure allowed me to substantially reduce the number of unique manufacturers' names from 255 278 to 89 365.

I identify a foreign manufacturer with its unique name (cleaned and standardized) and country from which it exports to Paraguay. Each location of a multinational firm is treated as a separate firm. To alleviate the impact of errors in names' cleaning on the results, I use only manufacturers with at least 1000 recorded transactions throughout the sample period in my analysis. For these manufacturers, I manually checked that the cleaning and standardization procedure performed on their names only remove spelling mistakes. They account for 75% of the total number of transactions in my sample.

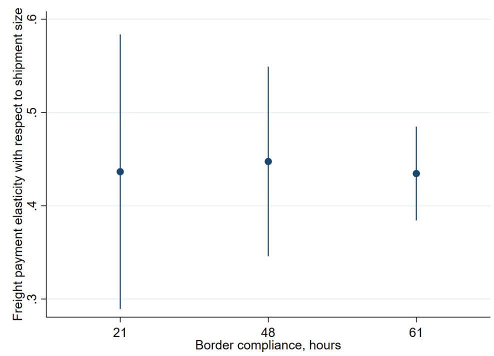
Procedures to clean and standardize declared transport companies' names

I apply similar procedures to clean and standardize reported transport company names. I first cleaned them from commonly used legal abbreviations (EIRL, SA, SRL, Group, Company, TRANSP, etc.), their country names, and large cities' names. Then I manually remove typos in the resulting transport companies' names. By doing this, I reduce the number of unique transport companies' names from 2700 to 1700.

To minimize the role of the names' cleaning procedure's errors in the results, I use only transport companies with more than 500 transactions in my analysis. For these transport companies, I manually checked that the cleaning and standardization procedures performed on their names correctly remove spelling mistakes. Transport companies reported in more than 500 transactions in the sample account for 83% of the total number of Paraguay's import transactions between 2013 and 2018.



(a) Within-container quantity discounts are not affected by time costs of paperwork



(b) Within-container quantity discounts are not affected by border compliance hours

Figure A8. Average quantity discounts are not driven by fixed transportation costs

Notes: Figures plot shipment's freight payment elasticities with respect to weight depending on country's documentary compliance costs (in hours) in (a) and border compliance costs (in hours) in (b). All coefficient are estimated off shipments from adjacent countries using container-country-HS2 fixed effects.

A.3 Additional results

Table A9. Modes of transportation of Paraguayan imports, 2013 - 2018

	Shipments, %	Weight, %	Value, %	Freight/Value, %
	Panel A: From Adjacent Countries			
Road	90	62	76	10
River	2	37	22	9
Air	8	1	2	15
	Panel B: From Non-adjacent Countries			
Road	35	19	31	13
River	37	80	51	15
Air	28	1	27	20

Table A10. Evidence of quantity discounts in maritime transportation in Peru

Dependent Variable:	$\log Freight_{icd}(\varphi)$			
	(1)	(2)	(3)	(4)
$\log Weight_{icd}(\varphi)$	0.797***	0.743***		
	(0.047)	(0.042)		
$\log Weight_{i}(\varphi)$	-0.059***	-0.067***		
	(0.015)	(0.016)		
$\log TEU_{icd}(\varphi)$			0.681***	
			(0.051)	
$\log TEU_{i}(\varphi)$			-0.023**	-0.020**
			(0.011)	(0.009)
$\log Containers_{icd}(\varphi)$				0.709***
				(0.088)
$20Foot$				-0.264***
				(0.068)
$\log Containers_{icd}(\varphi) \times 20Foot$				0.027
				(0.147)
Constant	0.611	1.271**	7.340***	7.690***
	(0.485)	(0.449)	(0.070)	(0.059)
Carrier×Vessel×Route	✓	✓	✓	✓
N obs	781	781	781	781
N clusters	22	22	22	22
Adj. R^2	0.910	0.882	0.830	0.835

* p<0.10, ** p<0.05, *** p<0.01

Standard errors clustered at exporter- and transporter- levels in parentheses.

Table A11. Quantity discounts unexplained by advance purchases of transportation across Peruvian exporters to Paraguay

Dependent Variable:	$\log Freight_{icd}(q)$			
	(1)	(2)	(3)	(4)
$N^{daysadvance}(\varphi)$	-0.139***	0.016		0.024
	(0.045)	(0.028)		(0.022)
$\log Weight_{icd}(q)$			0.407***	0.411***
			(0.048)	(0.050)
Constant	1.036***	0.132	4.228***	4.061***
	(0.316)	(0.207)	(0.270)	(0.319)
Year	✓			
Year-Mode		✓		
Container			✓	✓
N obs	825	825	140	140
N clusters	120	120	44	44
Adj. R^2	0.060	0.627	0.861	0.862

Standard errors clustered at exporter- and transporter-levels in parentheses.

* p<0.10, ** p<0.05, *** p<0.01

Notes: Shipment is identified with its Bill of Lading identifier. φ, i, c, and d denote exporter, transport company, route, and date of shipment. $N^{daysadvance}(\varphi)$ is the average number of days between shipping order and shipping dates of exporter φ in a year. Container identifies shipments on board of the same vehicle between the same pick-up and drop-off locations at the same time on the last leg of travel to Paraguay.

Table A12. Quantity discounts identified using a demand-side IV

Dependent Variable:	$\log Freight_{icd}(\varphi)$			$\log Weight_{icd}(\varphi)$
	(1)	(2)	(3)	(4)
	OLS	IV	OLS	I stage
$\log Weight_{icd}(\varphi)$	0.382***	0.488***		
	(0.016)	(0.086)		
$\log Weight_q(-\varphi)$			0.026***	0.052***
			(0.005)	(0.008)
Constant	3.673***		6.178***	6.719***
	(0.113)		(0.059)	(0.089)
Container-Country	✓	✓	✓	✓
N obs	84714	84714	84714	84714
N clusters	260	260	260	260
Adj. R^2	0.810	0.395	0.670	0.764
First-stage F		46.8		

Standard errors clustered at exporter- and transporter-levels in parentheses.
* p<0.10, ** p<0.05, *** p<0.01

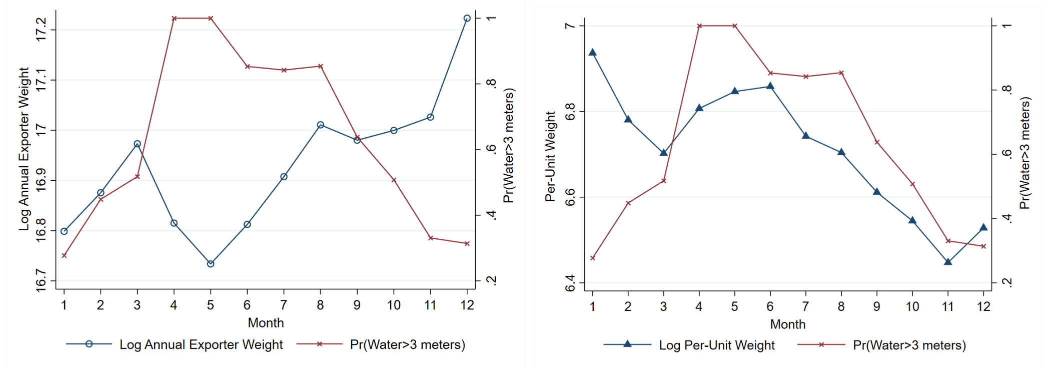
Notes: Shipment is identified with its Bill of Lading identifier. φ, i, c, and d denote exporter, transport company, route, and date of shipment. $Weight_q(-\varphi)$ is gross weight of shipments imported by an importer from all exporters other than φ in quarter q. Container identifies shipments on board of the same vehicle between the same pick-up and drop-off locations at the same time on the last leg of travel to Paraguay.

Table A13. The effect of competition of transport companies on freight prices

Dependent Variable:	$\log Freight_{icm}(\varphi)$				
	(1)	(2)	(3)	(4)	(5)
	OLS	IV	OLS	OLS	I stage
$\log Weight_{icmy}(\varphi)$	0.782***	0.675***	0.675***	0.675***	-0.002
	(0.006)	(0.003)	(0.003)	(0.003)	(0.008)
$\log N_{my}$	-0.378***				
	(0.102)				
$\log \hat{W}eight_{icmy}(\varphi) \cdot \log \hat{N}_{my}$		-0.024*	-0.117*		
		(0.013)	(0.060)		
$\log \hat{W}eight_{icmy}(\varphi) \cdot \hat{1}_{D_{my} \geq 3}$				-0.013**	0.109***
				(0.006)	(0.020)
$\log$ *Gas Price*$_{my}$	1.342***				
	(0.268)				
$\log$ *Currency*$(\varphi)/\$_{my}$	0.360**				
	(0.173)				
$\log$ *Guarani*$/\$_{my}$	-0.423*				
	(0.254)				
Constant	4.183*	1.850***		1.849***	0.013
	(2.196)	(0.028)		(0.028)	(0.076)
Transporter-Exporter-Year	✓				
Transporter-Country-Month		✓	✓	✓	✓
HS2-Month	✓	✓	✓	✓	✓
N obs	41129	98175	98175	98175	98175
N clusters	1457	1281	1281	1281	1281
Adj. R^2	0.929	0.792	0.667	0.792	0.184
First-stage F		21.2			

Standard errors clustered at the time-carrier level in parentheses.
* p<0.10, ** p<0.05, *** p<0.01

Notes: $Freight_{icmy}(\varphi)$ and $Weight_{icmy}(\varphi)$ denote total freight payment and gross weight (incl. packaging), respectively, transported from exporter φ in country c by transport company i in month-year my. N_{my} denotes the number of transport companies on the river. $1_{D_{my} \geq 3}$ is a dummy variable equals to one when permitted maximum vessel's draft in month-year my is above 3 meters and zero otherwise. $\hat{x}$ denotes x's deviation from its average in month m. HS2 is a 2-digit product code in HS classification.



(a) Larger exporters do not systematically export in months with high permitted draft

(b) Heavier products are not only exported in months with high permitted draft

Figure A9. Selection of exporters and products into shipping in months with high or low permitted draft

Notes: (a) plots annual exporter's weight (in logs) and probability of high permitted draft (above 3 meters) averaged by month across years. (b) plots per-unit gross weight of products exported to Paraguay (in logs) and probability of high permitted draft (above 3 meters) averaged by month across years.

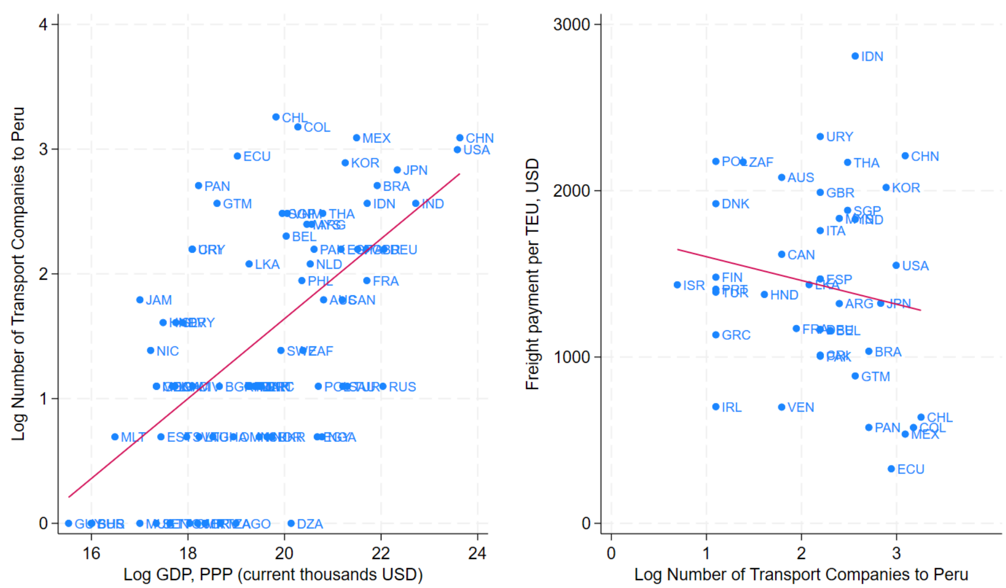


Figure A10. Larger countries have more transport companies transporting to Peru and lower freight prices per TEU

Table A14. Quantity discounts in transportation from Chile to Paraguay

Dependent Variable:	$\log Freight_{icd}(\varphi)$			
	(1)	(2)	(3)	(4)
$\log Weight_{icd}(\varphi)$	0.443***	0.432***		
	(0.014)	(0.039)		
$\log TEU_{icd}(\varphi)$			0.440***	0.432***
			(0.014)	(0.039)
Constant	3.950***	4.363***	8.064***	8.387***
	(0.117)	(0.252)	(0.050)	(0.129)
Transporter-Route-Date	✓	✓	✓	✓
Exporter organized		✓		✓
N obs	1982	150	1982	150
N clusters	402	58	402	58
Adj. R^2	0.867	0.898	0.862	0.898

Standard errors clustered at exporter-, transporter- levels in parentheses.
* p<0.10, ** p<0.05, *** p<0.01

Notes: Shipment is defined as a combination of exporter, transport company, date, port of lading and destination. Exporter-organized shipments are those with incoterms CFR, CIF, SCL, and DDP, as in Ardelean and Lugovskyy (2023). Route is defined as port of lading–destination. $Freight_{icd}(\varphi)$, $Weight_{icd}(\varphi)$ and $TEU_{icd}(\varphi)$ denote, respectively, freight payment, gross weight (incl. packaging) and volume (in twenty-foot equivalent units) of a shipment transported from exporter φ by transport company i at time d on route c.

Table A15. Exporters and importers in organizing transportation to Peru

Dependent Variable:	$\mathbb{P}r$ [*Exporter-organized shipment*]			
	(1)	(2)	(3)	(4)
log *Annual Exporter-Transporter TEU*	0.038***		0.046***	0.046***
	(0.005)		(0.005)	(0.005)
log *Annual Importer-Transporter TEU*		0.011**	-0.017***	-0.017***
		(0.005)	(0.005)	(0.006)
log *Shipment TEU*				0.001
				(0.007)
Constant	0.390***	0.467***	0.415***	0.415***
	(0.014)	(0.015)	(0.019)	(0.018)
Transporter-Vessel-Route-Date	✓	✓	✓	✓
N obs	59313	59313	59313	59313
N clusters	31	31	31	31
Adj. R^2	0.417	0.404	0.419	0.419

* p<0.10, ** p<0.05, *** p<0.01
Standard errors clustered at the transporter-level in parentheses.

Notes: Shipment is defined with its declaration number. Exporter-organized shipments are those with incoterms CFR, CIF, SCL, and DDP, as in Ardelean and Lugovskyy (2023). Route is defined as port of departure-port of receipt.

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