Endogenous Transportation Costs*

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Abstract

The containerized maritime transportation industry is characterized by oligopolistic competition and economies of scale. In this paper, we examine the effect that these industry characteristics have on trade. We build a model of endogenous transportation costs within a standard Melitz (2003) framework. Countries with large trade volumes face lower transportation costs because they can take advantage of economies of scale and competition in the transportation industry. We assemble a unique dataset on the containerized maritime transportation industry. The dataset includes the freight prices for transporting a container to a foreign port, the number of transportation firms operating between the US and foreign port, and the port-to-port trade flows. We document facts that are consistent with our theory. First, countries with larger trade volumes pay less in transportation costs. Second, countries with larger trade volumes have more and larger transportation firms. We then calibrate our model and estimate a transportation technology to evaluate trade reforms. Our results indicate that transportation costs fall more in smaller markets from tariff reductions. A model that considers the endogenous response of transportation costs to a trade liberalization generates welfare gains that are 50% more than a model in which transportation costs are constant.

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1 Introduction

A commonly made observation in the containerized maritime transportation industry is that larger trade flows lead to lower transportation prices.\(^1\) This industry is characterized by large economies of scale and oligopolistic competition. As trade flows increase, prices decrease because of economies of scale and increased competition among transportation firms. Understanding how transportation costs respond to trade flows is important to policymakers if they want to evaluate the effects of a trade reform. Standard trade models do not consider the response of the transportation industry to changes in trade flows and thus underestimate the effect of trade reforms. This is especially important because transportation costs are an important barrier that firms face when they want to export their goods.\(^2\)

In this paper, we contribute to the understanding of how this industry structure affects trade in three ways. First, we assemble a unique dataset on the containerized maritime transportation industry.\(^3\) We have chosen to look at one particular subset of the transportation industry and carefully collect industry data. Acquiring prices for transportation is difficult because of its confidential nature and accurate measures of transportation costs are rare.\(^4\,\,5\) Our pricing data is a clean measure of port-to-port transportation costs due to the standardization of shipping containers and the fact that it was collected from a common source at a

\(^1\)See Stopford [2009] and Rodrigue [2009] for example.
\(^2\)Anderson and van Wincoop [2004] indicate that the ad-valorem all-commodities arithmetic average is 10.7\% for the United States.
\(^3\)The vast majority of internationally manufactured goods are transported in shipping containers. The shipping container is a standardized metal box that can be easily transported by boats, trains, or trucks. The fact that it is standardized lowers the cost of loading and unloading. Levinson [2008] describes how the adoption of the container lowered transportation costs and made service more reliable and Rua [2012] studies the diffusion of containerized trade. Hummels [2007] and Dalton [2011] find that around 70\% of US imports of manufactured goods take place through maritime transport.
\(^4\)It is a well known problem that trade-weighted aggregate transportation costs are biased downwards because consumers substitute into goods that are cheaper to import. Furthermore, Hummels and Lugovskyy [2006] show that bilateral CIF/FOB ratios data, a commonly used measure, is unreliable because of its many imputed values and measurement errors.
We document that small transportation markets pay 67% more for transportation than do large markets. Second, we build a model with endogenous transportation costs in which firms in the transportation industry are oligopolistic competitors that enjoy economies of scale. The model generates predictions on how transportation prices respond to increases in trade flows. Lastly, using the assembled dataset on containerized maritime transportation industry, we calibrate the model and back out a transportation technology. We show that the traditional model can fail to capture significant portions of the gains that our model generates.

To introduce endogenous transportation costs, we embed a two-stage entry game of the transportation industry in a two-country Melitz (2003) framework. In the model, transportation firms pay a fixed cost in order to enter the market in the first stage and then compete a la Cournot in the second stage. Transportation firms operate a technology that has increasing returns to scale. As market size grows, transportation firms grow in size and become more profitable because of the economies of scale. The increased profits induces new firms to enter reducing transportation prices. The model accommodates market structures ranging from a monopolist firm to perfect competition as a function of market size.

The introduction of the transportation industry into a model of trade results in several key implications for the relationship between market size and transportation prices. First, smaller markets have higher transportation costs, fewer and smaller transportation firms.

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6The advantage of our pricing data over the data that comes from customs forms is that the latter data has heterogeneity across products, destination, and time that cannot easily be disentangled. In an attempt to recover port-to-port transportation costs from this data, we followed a procedure similar to Hummels [2007]. We estimated a regression in which the dependent variable is ad-valorem freight costs and the independent variables are time dummies and foreign port destination dummies using the Waterborne Databanks for 2000-2005. The result is that foreign port destination dummies are not statistically significant on over half the ports in our sample.

7The fact that our pricing data is a snapshot in time is especially important due to the volatility of worldwide transportation prices. The Baltic Dry, an index that tracks the price of moving commodities across major shipping lanes, declined from 2000 to 650 over the course of 2 months starting December 2011. The Shanghai Containerized Freight Index, which tracks containerized freight prices across major shipping lanes, also experiences large swings in prices.

8Few papers deal with the endogeneity of transportation prices and the effects on trade. Francois and Wooton [2001] study theoretically the implications of collusion within the maritime transportation industry on freight prices. Hummels et al. [2009], Hummels and Skiba [2002], Skiba [2007] empirically estimate how much transportation costs decline with trade volume.
Smaller markets will thus pay more because of the market power of transportation firms and the inability to take advantage of economies of scale. Second, how quickly transportation prices decline in relation to trade flows depends critically on the number of existing firms. Transportation markets with few firms will see large gains from increases in trade flows and markets with many firms will see relatively smaller gains. This indicates that a model with constant transportation costs can underpredict the effects in markets with a small number of transportation firms.

In the quantitative part of the paper, we calibrate the model and back out a transportation technology. We then simulate a small tariff reduction and show that our model delivers welfare gains that are 50% more than a model in which transportation costs are constant. We also show that the gains from endogenous transportation costs depend critically on the number of existing shippers in the market. As the number of shippers increases, the predictions of our model and the model with constant transportation costs converge.

What do our results imply for evaluating welfare gains from trade liberalizations in general? The answer will depend on the mode of transport primarily used between two countries that liberalize trade. Neighboring countries mainly use land transportation but for non-contiguous countries maritime transportation is by far the most important method of moving goods. Excluding land trade, 40% of US imports are containerized maritime and 70% of US imports are waterborne. Evidence from the transportation literature indicates that economies of scale in non-containerized maritime shipping are also significant.9

This paper is structured as follows: Section 2 describes the constructed dataset on transportation prices and the key features of the data. Section 3 lays out a model of endogenous transportation costs. Section 4 details the calibration of the model. Section 5 reports the results from the quantitative exercise. Section 6 concludes.

9See Christiansen et al. [2007].
2 Empirical Analysis

In Section 2.1 we describe the construction of our dataset on the containerized liner shipping industry.\textsuperscript{10} In Section 2.2, we study the summary statistics of this data and find that there are large dispersions in freight prices, the number of firms that service destination ports, and measures of scale. In Section 2.3, we analyze how prices are correlated with distance, the number of active firms, and measures of scale. We summarize our findings by looking at the characteristics of small and large markets. We also use an IV procedure commonly used in the empirical literature to assess how transportation prices decline with trade flows.

2.1 Constructing the Dataset

2.1.1 Freight Prices

Data on freight prices were obtained from the freight forwarder\textsuperscript{11} Air Parcel Express (APX). The advantage of this data is that it is a snapshot of market prices taken at one point in time from a consistent source. The freight prices\textsuperscript{12} are for transporting a 20 foot container from the Port of Los Angeles/Long Beach, Charleston, New York/Newark, and Oakland to over 250 different destination ports in August 2012.\textsuperscript{13}

\textsuperscript{10}The data is for the containerized liner shipping industry, which means that transportation firms make regularly scheduled stops at specified ports. The fact that it is regularly scheduled implies that there are larger entry costs because a firm must commit to regularly service a market. The alternative is tramp operations which do not have fixed schedules and are often hired to conduct a single voyage. This mode of transport is mainly used for non-containerized trade, which is transported unpackaged on the ship in large volumes (commonly commodities such as iron ore and coal). Hummels et al. [2009] indicate that tramp ships transport less than 5% of US containerized import cargo by value.

\textsuperscript{11}A freight forwarder is third party logistics provider. Freight forwarders advise exporters on freight costs and other fees (port charges, consular fees, costs of special documentation, insurance costs, and handling fees), as well about import rules and regulations, the methods of shipping, and the necessary documents related to foreign trade.

\textsuperscript{12}The freight price includes the base freight price charged by the shipper and any additional surcharges. The most common surcharge is the Bunker Adjustment fee, which changes depending on the price of oil. Other charges, such as the transportation cost to the port, insurance, and the cost of completing paperwork (such as the Bill of Lading) were not included since these are not subject to the increasing returns to scale nature of the shipping technology.

\textsuperscript{13}Los Angeles and Long Beach, and New York and Newark are two separate ports that are adjacent to each other. We combine data from these ports.
2.1.2 Route Structure and Number of Competitors

Data on the number of competing transportation firms was assembled using information from Containerisation International, a firm that collects and sells data specifically about containerized shipping to industry participants. From the yearbooks that this firm publishes, we collected data on every vessel engaged in container shipping globally. We also collected data on every container port that operates in the world. From these two sets of data, we identified every line on a global basis and constructed a map of network connectivity. This data constitutes the route structure of the containerized liner service industry. At the end of the process, we have data on each containerized shipping line, the ports on the line, the number of ships, the total capacity of these ships, and the company operating this line. We also have information about strategic alliances that operate shipping lines.\(^{14}\)

2.1.3 Total Container Traffic by Port

From the Containerisation International yearbooks, we also assemble data on the total container traffic for all the ports in the world of the recent past. For every port, we have data on the total number of 20 foot containers that were loaded and unloaded at the port each year.

2.1.4 Port-to-Port Containerized Trade Flows

Data on port-to-port containerized trade flows came from Waterborne Databanks issued by the US Maritime Administration for the years 2000-2005. The dataset contains information about US international maritime trade on a port-to-port level. The data is broken down to the HS 6 product level and includes the cost of transportation and insurance, weight, and whether the shipment is containerized. The dataset also details whether the container was

\(^{14}\)A strategic alliance involves several firms jointly managing a shipping line in order to take advantage of economies of scale. These alliances have become increasingly important since the mid 1990s. Mega alliances such as the Grand Alliance, New World Alliance and CKYH Alliance control increasing levels of market share. See Panayides and Wiedmer \cite{Panayides2011} for more information.
transshipped through a regional shipping hub. Transhipment occurs when there are no ships that travel directly from the origin to destination. For example, a container that goes from Los Angeles to Thailand may first go to Hong Kong. To update the containerized trade flows to the most recent year, we increase the size of the trade flows by the increase in bilateral trade between two country pairs.

2.1.5 Port-to-Port Distances

Distance data, measured in nautical miles, came from the online distance calculator offered by Sea Rates, a website that connects exporters to freight forwarders. The data is of the shortest navigable distance between two ports. For example, the calculator considers the fact that a boat going from Los Angeles to Europe can cross the Panama canal.

2.1.6 Containerized Trade per Shipping Firm

Using the port-to-port containerized trade flows and the number of competitors, we calculate the average trade flow per transportation firm. This gives us a measure of the average size of transportation firms between any two ports in our sample.

2.2 Describing the Data

In this section, we first show that there are large dispersions in transportation prices across destinations. We also that there are huge differences in measures of scale (both in terms of total trade flows by destination port and trade flows per firm) and the number of active firms across these destinations.

We will only analyze the data for ports that have a shipping line that connects it with a U.S. port. The reason is that it allows us to easily determine the number of shippers that are present between two ports without having to think about potential competitors through transhipment, which is difficult to determine in the data.
2.2.1 Dispersion of Freight Prices

There are large differences in prices across destinations to transport a container. Figure 2.1 shows the entire distribution of freight prices in our dataset for which there is more than one shipper. The mean destination has a price of $1939 and the standard deviation is $570. The large number of destinations with prices around $1,000 are Asian destinations that enjoy low prices due to a large trade imbalance between the US and East Asia.\(^{15}\)

![Figure 2.1: Distribution of Freight Prices](image)

2.2.2 Dispersion of Number of Competitors

Next, we will look at the number of competitors across destinations. The distribution of the number of competitors for destination ports that have at least one transportation firms serving the foreign port is shown in Figure 2.2. About 50% of our sample has monopolist shippers and about another 20% has two shippers. However, there are some destinations that have a very large number of firms. For example, Los Angeles to Shanghai has 12 shippers.

\(^{15}\)Trade imbalances have implications for transportation prices. For example, in 2008 the merchandise exports from the United States Asia used 5.6 million containers and merchandise exports from Asia to the United States used 14.5 million containers. Thus, 8.9 million containers need to be re-positioned. In fact, by 2005 70% of the slots of containerships leaving the United States were empty. Thus, Asian exporters pay on average 50% more in container shipping costs than American exporters.
2.2.3 Dispersion of Total Container Traffic by Port

The first measure of scale is total container traffic by port, shown in Figure 2.3. The distribution closely resembles log normal, which means that it is skewed in the right tail. Furthermore, this skewness is reflected in the fact that the mean of the distribution is 6.2 million containers and the median is 1.5 million containers. The differences across the size of ports are significant: the port in the 10th percentile has container traffic of 240,000 and the port in the 90th percentile has traffic of 5,400,000, which is 22 times the size of the smallest port.
2.2.4 Dispersion of Port-to-Port Containerized Trade Flows

We turn our attention to port-to-port containerized trade flows, as shown in Figure 2.4, as another measure of economies of scale. We find that the dispersion is an order of magnitude larger than the dispersion of total container traffic. The distribution also appears lognormal, and the mean of the distribution is $2,400 million and the median is $500 million. The differences across the port-to-port containerized trade flows are huge: the port in the 10th percentile has trade flows of $25 million and the port in the 90th percentile has trade flows of $5,800 million, which is 232 times the trade flows of the destination port with small trade flows.

Figure 2.4: Distribution of Port-to-Port Containerized Trade Flows

2.2.5 Dispersion of Containerized Trade per Shipping Firm

We now look at the containerized trade per shipping firm as constructed in section 2.1.6 as our last measure of economies of scale. The distribution of the log containerized trade per shipping firm is shown in Figure 2.5. This distribution also seems lognormal, meaning that the distribution is highly skewed in the right tail. The mean of the distribution is $780 million and the median is $380 million. Like port sizes and port-to-port containerized trade flows, the differences across containerized trade per shipping firm are significant: the port in the 10th percentile has trade flows of $20 million and the port in the 90th percentile has
trade flows of $1,800 million, which is 90 times the containerized trade per shipping firm for the small port.

![Figure 2.5: Distribution of Containerized Trade per Shipping Firm](image)

2.3 Documenting Empirical Relationships

In this section, we investigate how prices are correlated with distance, the number of active firms, and measures of scale. We also compare the characteristics of small and large markets in terms of these measures. Lastly, we will use a methodology similar to the one used in the empirical literature to estimate how transportation costs decline with trade flows.

2.3.1 Freight Prices and Distance

A striking feature of the pricing data is the relationship with distance, as shown in Figure 2.6. The correlation is only around -0.08. It is interesting to note that the highest and lowest observations in the scatterplot are roughly at equal distance (around 5,000 miles).

Figure 2.7 shows the distribution of prices for Los Angeles across countries. The map shows the transportation price to foreign countries using the average price for ports located in that country. European countries pay roughly the same if not less than some Central American countries, even though the latter are much closer and are on the path most Europe-bound ships take. Africa also pays significantly more than Europe even though they are both
at roughly the same distance.

2.3.2 Freight Prices and Number of Transportation Firms

As a next step we analyze how prices are related to the number of active transportation firms. Figure 2.8 is the same as Figure 2.6 except that destinations served by monopolist shippers are distinguished from the rest. The graph shows that destinations that have monopolist shippers generally have higher prices.
2.3.3 Freight Prices and Scale of Operation

Next, we study how the scale of operation is related to freight prices. Figure 2.9 shows the relationship between freight price and the containerized trade per shipping firm (as described in Section 2.2.5). There is a negative correlation of -0.46 between the two variables meaning that destinations that have larger firms also have lower transportation costs.

2.3.4 Characteristics of Small vs Large Transportation Markets

Next, we compare the difference between small and large markets by comparing the bottom 20% with the top 20% of our sample in terms of port-to-port containerized trade flows. The
results are reported in Table 1.

The differences across market size is dramatic. First, large markets are considerably larger than the small markets: the average large market is 374 times the size of a small market. Furthermore, the trade flows per firm in the large markets is 108 times that of the small market. Large markets also have 3 times as many transportation firms. Large markets also enjoy prices that are 40% lower than those of the small market. Lastly, the large markets are 44% further away than the small markets.

Table 1: Comparing Small and Large Transportation Markets

<table>
<thead>
<tr>
<th></th>
<th>Bottom 20%</th>
<th>Top 20%</th>
<th>Top / Bottom 20%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price ($)</td>
<td>2,330</td>
<td>1,390</td>
<td>0.60</td>
</tr>
<tr>
<td>Number of firms</td>
<td>1.55</td>
<td>4.95</td>
<td>3.19</td>
</tr>
<tr>
<td>Containerized trade flows / firm (millions $)</td>
<td>23</td>
<td>2,493</td>
<td>108.39</td>
</tr>
<tr>
<td>Containerized trade flows (millions $)</td>
<td>27</td>
<td>10,120</td>
<td>374.81</td>
</tr>
<tr>
<td>Distance (naut. miles)</td>
<td>3,990</td>
<td>5,730</td>
<td>1.44</td>
</tr>
</tbody>
</table>

2.3.5 Freight Prices and Trade Volumes

We will now follow the empirical literature as a baseline to see how freight price are related to trade volumes. We now estimate the following regression

$$\log(Price_{ij}) = \alpha_1 \log(TradeVolume_{ij}) + \alpha_2 \log(X_{ij}) + \alpha_3 + \epsilon_{ij}$$

$j$ is the foreign port, $i$ is the US port, and $X$ is a set of controls.

In estimating this regression we face an issue with the endogeneity of trade volumes. We will follow Hummels and Skiba [2002] and instrument for trade volume using the population of the country.\footnote{Using population as an instrument is common in the empirical trade literature. For example, see Frankel et al. [1996].} To use population as an instrument, it must be relevant (correlated to trade volumes) and valid (not correlated to the error term). The correlation between trade...
volume and population is 0.41, which means that the instrument is relevant. The instrument is valid as changes in population do not affect the supply side.

We control for fixed effects that include an origin port dummy and a foreign region dummy. Table 2 shows the results. First, the estimates on the coefficient of trade volume change dramatically when we include instrument variable, which confirms that trade volume is endogenous. Column 3 indicates that a 1% increase in trade volume leads to a 0.191% decline in transportation costs once we control for observed factors and fixed effects. In the quantitative section, we will compare our results from our calibrated model with those of the reduced form estimates.

<table>
<thead>
<tr>
<th></th>
<th>( \log(\text{Price}_{ij}) )</th>
<th>( \log(\text{Price}_{ij}) )</th>
<th>( \log(\text{Price}_{ij}) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \log(\text{TradeVolume}_{ij}) )</td>
<td>-0.083*** (0.007)</td>
<td>-0.065*** (0.009)</td>
<td>-0.191*** (0.038)</td>
</tr>
<tr>
<td>Distance</td>
<td>0.233*** (0.036)</td>
<td>0.122** (0.059)</td>
<td></td>
</tr>
<tr>
<td>Total container traffic foreign port</td>
<td>-0.037*** (0.014)</td>
<td>0.043 (0.030)</td>
<td></td>
</tr>
<tr>
<td>GDP per capita</td>
<td>0.070*** (0.019)</td>
<td>0.083*** (0.027)</td>
<td></td>
</tr>
<tr>
<td>Foreign port quality</td>
<td>0.081 (0.070)</td>
<td>-0.061 (0.106)</td>
<td></td>
</tr>
<tr>
<td>English official language</td>
<td>0.122** (0.043)</td>
<td>0.086 (0.060)</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Fixed effect controls</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>( R^2 )</td>
<td>0.35</td>
<td>0.63</td>
<td>0.25</td>
</tr>
<tr>
<td>obs</td>
<td>206</td>
<td>206</td>
<td>206</td>
</tr>
</tbody>
</table>

***, **, * indicate statistical significance of 1%, 5%, 10% respectively
3 Model

We describe a Melitz [2003] model in which there are two countries, home $h$ and foreign $f$. The transportation industry is modeled as a two-stage entry game with Cournot competition. Transportation firms charge production firms $\tilde{p}$ in order to transport one unit of consumption good to the other country.

3.1 Consumer’s Problem

Country $h$ is populated by identical consumers of measure $\bar{\ell}_h$. Each agent supplies one unit of labor to the market and spends his income on a continuum of domestic and imported goods indexed by $v$. The representative consumer of country $h$ takes prices $p^h(v)$, $p^f(v)$, and wage $w_h$ as given and chooses consumption of home and foreign goods, $c^h(v)$ and $c^f(v)$ respectively, to solve

$$\max_{c^h(v), c^f(v)} \left( \alpha_h \int_{v \in \Omega^h_i} c^h(v)^\frac{\sigma - 1}{\sigma} dv + (1 - \alpha_h) \int_{v \in \Omega^f} c^f(v)^\frac{\sigma - 1}{\sigma} dv \right)^{\frac{\sigma}{\sigma - 1}}$$

subject to

$$\int_{v \in \Omega^h_i} p^h(v)c^h(v)dv + \int_{v \in \Omega^f} \tau^h f p^f(v)c^f(v)dv = w_h \bar{\ell}_h + T_h$$

$\Omega^j_i$ is the set of goods from country $j$ available in country $i$, $\sigma$ is the elasticity of substitution, and $\alpha_h$ are expenditure weights on goods produced at home. $\tau^h f$ is the tariff charged by country $h$ and is paid by consumers in country $h$.

The solution to the consumer’s problem in country $h$ for goods from country $f$ is

$$c^f(v) = \frac{(1 - \alpha_h) w_h \bar{\ell}_h}{(\tau^h f p^f(v))^{\frac{1}{\sigma}} P^h_1 - \sigma}$$

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17Our model of the transportation industry can also be embedded in other models of trade. We chose Melitz [2003] since Ruhl [2008] has shown that this class of models can replicate the large increases in trade flows observed after trade liberalizations.
\[ P_h^{1-\sigma} = \int_{v \in \Omega_h} p_h^h(v)^{1-\sigma} dv + \int_{v \in \Omega_f} (\tau_j^f p_f^h(v))^{1-\sigma} dv \]  

(3.3)

\( P_h \) is the price index of country \( h \).

### 3.2 Production Firm’s Problem

There is an infinite mass of potential entrants. A potential entrant in country \( j \) pays fixed cost \( w_j F \) to enter the market and draws a productivity \( \phi \) from Pareto distribution with CDF \( G(\phi) = 1 - \left( \frac{\phi}{b} \right)^\gamma \), where \( \phi \geq b \) (\( b \) is the minimum draw) and \( \gamma > \sigma \). A firm with productivity level \( \phi \) has a labor requirement of \( \frac{1}{\phi} \) to produce one unit of consumption good.

Firms that only produce in the domestic market do not pay any additional fixed costs. Exporting firms must pay fixed cost \( w_h F_{exp} \) to access the foreign market, and it must pay transportation cost \( \tilde{p} \) for each unit of consumption good exported.

#### 3.2.1 Pricing Decision

Firm \( v \) in country \( h \) that enters market \( i = h, f \) takes aggregate prices, wages, and transportation prices \( \tilde{p}_i^h \) as given and solves

\[ \pi_i^h(v) = \max_{p_i^h(v)} \left( p_i^h(v) c_h^i(v) - c_i^h(v) \frac{w_h}{\phi(v)} - \tilde{p}_i^h c_i^h(v) \right) \]  

(3.4)

There are no domestic transportation costs, \( \tilde{p}_h^h = 0 \) and \( \tilde{p}_h^h = \tilde{p} \). The firms that enter market \( i \) will set

\[ p_i^h(v) = \frac{\sigma}{\sigma - 1} \left( \frac{w_h}{\phi(v)} + \tilde{p}_h^i \right) \]  

(3.5)

The pricing rule, profitability of the firm, and the consumer’s consumption decision only depend on the firm’s productivity. In what follows we will no longer characterize a good by its label \( v \) but by the productivity \( \phi \) of the firm.
3.2.2 Exporting Decision

Since \( \pi_h^f(\phi) \) is increasing in \( \phi \), there is a minimum productivity cutoff \( \hat{\phi}_h^f \) to export characterized by

\[
\pi_h(\hat{\phi}_h^f) = w_h F_{\text{exp}} \tag{3.6}
\]

3.2.3 Free Entry Conditions

The number of firms that draw and operate domestically, \( M_h \), is determined by the free entry condition

\[
\bar{\pi}_h = w_h F \tag{3.7}
\]

The expected profit is

\[
\bar{\pi}_h = \int_{b}^{\infty} \pi_h^h(\phi) dG(\phi) + \int_{\hat{\phi}_h^f}^{\infty} \pi_h^f(\phi) dG(\phi)
\]

The mass of exporters in the home country, \( M_{\text{exp}, h} \), is determined by

\[
M_{\text{exp}, h} = \left(1 - G(\hat{\phi}_h^f)\right) M_h \tag{3.8}
\]

3.3 Transportation Industry

The transportation industry is a two-stage entry game. In the first stage, \( M \) shippers enter the market to transport goods between countries \( i \) and \( j \) by paying fixed cost \( F_T \). In the second stage, firms compete a la Cournot. The transportation industry is owned and operated by country \( h \).
3.3.1 Demand for Transportation

The demand for transportation is

\[ Q = \int_{v \in \Omega_h^f} c^f_h(v) dv + \int_{v \in \Omega_f^h} c^h_f(v) dv \]  

(3.9)

Note that \( Q \) is strictly decreasing in \( \tilde{p} \) since \( c^f_h(v) = \frac{(1-\alpha_h)w_h\ell_h}{(\tau^f_h P^f_h(v))^{1-\sigma}} \) and \( p^h_f(v)\sigma \) and \( P^{1-\sigma} \) are strictly increasing in \( \tilde{p} \). Let \( \tilde{p}(Q) \) be the indirect demand function.

3.3.2 Second Stage Transportation Firm Problem

We work backwards through the entry game and start in the second stage. Suppose that \( M \) shippers have entered the market. Firms have transportation technology

\[ T = \phi^T \ell^T \]

where \( T \) is the quantity of consumption good transported.\(^{18}\)

Shipping firm \( m \) takes competitors quantity supplied \( Q_{-m} \) as given and chooses \( Q_m \) and solves

\[ \max_{Q_m} Q_m \left( \tilde{p}(Q_m + Q_{-m}) - \frac{w_h}{\phi^T} \right) \]  

(3.10)

There is a unique symmetric equilibrium, so we can write the profit as a function of the number of transportation firms

\[ \pi^M = \frac{Q}{M} \left( \tilde{p} - \frac{w_h}{\phi^T} \right) - w_h F^T \]  

(3.11)

3.3.3 First Stage Transportation Firm Problem

In the first stage, the number of shippers that enter the market \( M \) is determined by the free entry condition

\(^{18}\)Note that firms have increasing returns to scale because in the first stage they paid a fixed cost. Thus, the average cost curve is declining with quantity.
\[ \pi^M = 0 \] (3.12)

\( M \) is a continuous variable.

### 3.4 Trade and Labor Clearing Conditions

The trade condition between \( h \) and \( f \) is

\[ M_f \int_{\hat{\phi}_f}^{\infty} p_f^i(\phi) c_h^j(\phi) dG(\phi) = M_h \int_{\hat{\phi}_h}^{\infty} p_h^i(\phi) c_f^j(\phi) dG(\phi) + \tilde{p} M_f \int_{v \in \Omega_f} c_f^j(\phi) d\phi \] (3.13)

\( \tilde{p} M_f \int_{v \in \Omega_f} c_f^j(\phi) d\phi \) is the value of transportation services provided by country \( h \) to \( f \).

The labor clearing condition in country \( h \) is

\[ M_h \int_{\phi}^{\infty} \frac{c_h^j(v)}{\phi(v)} dG(\phi) + M_h \int_{\hat{\phi}_h}^{\infty} \frac{c_f^j(v)}{\phi(v)} dG(\phi) + F M_h + F_{exp} M_{exp.h} + \frac{Q}{\phi_T} + M F^T = \bar{\ell}_h \] (3.14)

\[ M_f \int_{\phi}^{\infty} \frac{c_h^j(v)}{\phi(v)} dG(\phi) + M_f \int_{\hat{\phi}_f}^{\infty} \frac{c_f^j(v)}{\phi(v)} dG(\phi) + F M_f + F_{exp} M_{exp.f} = \bar{\ell}_f \] (3.15)

### 3.5 Equilibrium

**Equilibrium.** For \( i, j = h, f \), an equilibrium is a set of allocations of consumption good \( \{c_j^i(\phi)\} \), export thresholds \( \{\phi_j^i\} \), prices for the production good firm \( \{p_j^i(\phi)\} \), price for transporting one unit of consumption good \( \tilde{p} \), quantity of goods transported \( Q_m \) and \( Q \), and aggregate variables \( \{w_i, P_i\} \) such that

1. Given \( \{w_i, p_j^i(\phi)\}, \{c_j^i(\phi)\} \) is given by 3.2 and solves the consumer’s problem in 3.1.

2. Given \( \{w_i, P_i, \tilde{p}\} \) and \( \{c_j^i(\phi)\} \) as given by 3.2, \( \{p_h^i(\phi)\} \) is given by 3.5 and solves the problem of the firm with productivity \( \phi \) in 3.4 for all \( \phi \) when \( i = h \) and for all \( \phi \geq \hat{\phi}_h^i \) when \( i = f \).
3. Given \( \{w_i, P_i\}, \{c^i_j(\phi)\}\) as given by 3.2, and \( \{p^i_h(\phi)\}\) as given by 3.5, \( Q_m \) solves the transportation firm’s problem in 3.10, \( \tilde{p} \) satisfies 3.9, and \( Q = Q_mM \).

4. Given \( \{\pi^M\} \) in 3.11, \( M \) satisfies the free entry condition in 3.12.

5. \( \{\hat{\phi}^i_j\} \) satisfies 3.6.


### 3.6 Characterizing the Transportation Industry Model

We now discuss why increases in market size lead to declines in transportation prices as well as more and larger transportation firms. Suppose that there is an increase in market size. The existing firms in the market grow in size and become more profitable due to the economies of scale of the transportation technology. The increased profit induces new firms to enter the market, reducing transportation prices.

The Cournot structure of our model accommodates a wide range of market structures. Suppose that there is a market that is only big enough for a monopolist shipper. This monopolist will accordingly charge monopolist markups. As market size grows, the number of firms in the market will grow and markups will decline. As market size continues to grow and more firms enter, our model will approach perfect competition where all firms charge marginal cost.\(^{19}\)

Another important implication of the Cournot setup is that the rate at which transportation prices decline is not uniform. For example, an increase in trade is going to lead to a much larger decline in transportation prices in monopolistic markets than in markets with many firms. This is because the monopolistic market has not taken as much advantage of the reductions in market power and economies of scale. This result will play an important

\(^{19}\)These results for a Cournot setup are discussed by Sutton [1991].
role in the next section because it predicts that the gains from lower transportation prices will be larger in ports with few competitors.

4 Calibration

4.1 What is a Country?

A country in our model corresponds to the entire area serviced by a port in the data. For example, the country of Los Angeles is the entire area that is serviced by this port. To determine the GDP of the country, we use data on port-level inbound and outbound container traffic from Containerisation International. The GDP of a port is the GDP of the country the port is located in multiplied by the fraction of the country’s containers that go through that port.

Although our data is on a port-to-port basis, it is largely consistent with country-to-country gravity equation estimates. The gravity equation is an extremely robust empirical fact that bilateral trade between two countries is proportional to their respective sizes, measured by their GDP, and inversely proportional to the geographic distance between them. A gravity style regression using the new definition of a country results in coefficients on foreign GDP of 0.98 and on distance of -0.72. Disdier and Head [2008] conducted a meta-analysis of the empirical gravity equation literature and find that the average coefficient on distance is around -0.90 and on GDP around 1.

4.2 What is a Firm?

A transportation firm in our model corresponds to the number of firms that transport goods between two given ports. A transportation firm is not an entire shipping firm that operates on a global basis, but simply the decision of the firm to make a stop at the destination port. One important feature of the industry is that there are important economies of scope in offering transportation services over a network of ports. For example, vessels traveling
between the West Coast of the United States and East Asia will often stop at Los Angeles and Oakland before going to Asia where it will stop at series of ports. Thus, the cost of entering a destination is the cost associated for a ship to make the additional stop at that foreign destination given the present network structure of the industry.

4.3 Trade Model Parameters

The parameters and target statistics that vary by US/foreign port combination are reported in Table 3. The labor endowment of the US port $\bar{\ell}_h$ is normalized to 1. The labor endowment of the foreign port $\bar{\ell}_f$ is set to match the GDP of the foreign port. The home bias parameters $\alpha_h$ and $\alpha_f$ are set to match the openness of the two ports. Tariffs are set to the bilateral trade-weighted averages in the data as reported by World Bank WITS.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Symbol</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor endowment</td>
<td>$\bar{\ell}_h$</td>
<td>Normalized to 1</td>
</tr>
<tr>
<td>Labor endowment</td>
<td>$\bar{\ell}_f$</td>
<td>GDP of foreign port</td>
</tr>
<tr>
<td>Home bias</td>
<td>$\alpha_h$, $\alpha_f$</td>
<td>Value trade / GDP of both ports</td>
</tr>
<tr>
<td>Tariffs</td>
<td>$G^f_h$, $G^h_f$</td>
<td>Trade-weighted tariffs</td>
</tr>
</tbody>
</table>

Parameters and target statistics that are common across all ports are reported in Table 4. $F_{exp}$ is set to match the fact that 18% of US manufacturing firms export. For each US port we take the foreign port in which the maximum percentage of firms exported. Then, the sum (weighted by GDP) over US ports is set to 18%.

$\gamma$ is chosen to match the fact that exporting firms have 26% higher value-added per worker as reported by Bernard et al. [2007]. For each US port we find the the average exporter value-added premium per worker over all destination ports. The sum (weighted by GDP) over the US ports is set to 26%.

---

20 The GDP of a port is defined to be the sum of the value of consumption, investment, and net exports. As in Gibson [2007], the sunk cost of entry $F$ is thought of as the purchase of fixed capital and is thus part of investment. Net exports is characterized by equation 3.13.

21 Trade costs that we do not consider are “soaked up” by the home bias parameter. Obstfeld and Rogoff [2000] discuss that home bias can be mapped isomorphically to trade costs.
The elasticity of substitution is set to $\sigma = 2.9$ following Feenstra [2010].\textsuperscript{22} Finally, the fixed cost to operate $F$ is normalized to 1.\textsuperscript{23}

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Symbol</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed cost to export</td>
<td>$F_{exp}$</td>
<td>18% of plants export</td>
</tr>
<tr>
<td>Tail parameter</td>
<td>$\gamma$</td>
<td>Exporters’ value-added per worker 26% higher</td>
</tr>
<tr>
<td>Minimum draw</td>
<td>$b$</td>
<td>Normalized to 1</td>
</tr>
<tr>
<td>Elasticity of substitution</td>
<td>$\sigma$</td>
<td>2.9</td>
</tr>
<tr>
<td>Fixed cost to enter</td>
<td>$F$</td>
<td>Normalized to 1</td>
</tr>
</tbody>
</table>

### 4.4 Transportation Model Parameters

The parameters for the transportation model are described in Table 4.4. For each US-foreign port pair, we must find the fixed cost $F_T$ and the unit labor requirement $\frac{1}{\sigma_T}$. The fixed cost is set to match the observed number of firms that are operating between the two ports. There are many fixed costs that are consistent with the number of firms in the data, so we choose the fixed cost so that there $\frac{M + (M + 1)}{2}$ firms operating.

The unit labor requirement is set to match a target $\bar{p}$. We set the ratio of prices across all foreign destinations to match the price dispersion in the assembled data. The level of prices is set to match the trade weighted transportation of that port to the world.\textsuperscript{24}

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Symbol</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed cost</td>
<td>$F_T$</td>
<td>$\pi \frac{M + (M + 1)}{2} = 0$, M is shippers in data</td>
</tr>
<tr>
<td>Unit labor requirement</td>
<td>$\frac{1}{\sigma_T}$</td>
<td>Target $\bar{p}$</td>
</tr>
</tbody>
</table>

The intuition behind the identification of the transportation model parameters is simple. Suppose that there is a destination that has very large trade flows and has few shippers. The

\textsuperscript{22} Feenstra [2010] takes the median value of $\sigma$ across the 4-digit SITC industries imported by a country. He reports that this median estimate is tightly distributed around 2.9.

\textsuperscript{23} $F_{exp}$ is expressed in terms of $F$.

\textsuperscript{24} The trade-weighted transportation costs are calculated from the 2005 Waterborne Databanks.
model rationalizes the data by assigning it a relatively large fixed cost. Suppose that for a given number of shippers we observe a high price in the market, then the model rationalizes the data by assigning it a high unit labor requirement.

### 4.5 Calibration of the Model with Constant Transportation Costs

We also calibrate a model in which the transportation industry is characterized by perfect competition. In this setting, the price will always remain the same. We use the parameter targets as in Tables 3 and 4. The marginal cost is set to match the ratio of observed prices in the collected dataset. Thus, the level of the marginal costs is set so that the trade-weighted transportation costs that we observe in the data for that port matches that in the model. In this model, all fixed cost for transporation firms are set to zero.

### 5 Quantitative Results

#### 5.1 What do the Transportation Fixed Costs Look Like?

There is a very large dispersion in the fixed costs across destinations. In Table 6, we compare the destination in the 90th vs the 10th percentile in terms of fixed cost. We compare each port separately because the units of the fixed cost are in terms of the labor endowment of the US port, which was normalized to 1 in the calibration. We find large dispersions in fixed costs across destinations. In the average US port in our sample, the destination in the 90th percentile is 73x larger than the destination in the 10th percentile. We look at three possible factors that can be correlated to these fixed costs: distance, marginal cost, and the quality of the foreign port.

We first analyze the the correlation between the fixed cost and marginal cost, as shown in Figure 5.1. We see that there is a strong negative correlation between the fixed cost and the marginal cost. Across the US ports that we studied, the average correlation between $\log \frac{1}{\sigma}$ and $\log F^T$ was -0.57, suggesting that there is a technological choice that shippers face. In
other words, shippers can choose to undertake a larger fixed cost in order to lower variable cost. Next, we analyze the correlation between distance and the fixed costs, as shown in Figure 5.2. Across the US ports that we studied, the average correlation between log $dist$ and log $F^T$ was 0.48. Lastly, we find in Figure 5.3 that the quality of the foreign port is not highly correlated to the fixed cost.

Figure 5.1: log(MC) vs log(FC)

<table>
<thead>
<tr>
<th>Port</th>
<th>10% percentile</th>
<th>90% percentile</th>
<th>90/10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charleston</td>
<td>0.001123</td>
<td>0.027640</td>
<td>22</td>
</tr>
<tr>
<td>Los Angeles</td>
<td>0.000275</td>
<td>0.016243</td>
<td>59</td>
</tr>
<tr>
<td>New York</td>
<td>0.000236</td>
<td>0.021466</td>
<td>90</td>
</tr>
<tr>
<td>Oakland</td>
<td>0.000074</td>
<td>0.018515</td>
<td>124</td>
</tr>
</tbody>
</table>

### 5.2 Simulate 1% Decrease in Tariffs

We now simulate a 1% decline in tariffs and analyze the impacts on the cross-section of foreign ports. The results will be broken down by the number of existing firms in the market before the liberalization because this is a critical factor in how responsive price change will be to increased trade flows.
5.2.1 More and Larger Firms Transportation after Trade Reform

First we confirm the predictions in Section 3.6 that after a liberalization there are more transportation firms and they are larger. Table 7 shows the results from the simulation. The percentage increase in the the number of firms was highest in the case of one firm and drops quickly with two shippers. The third column indicates that the average firm size also increased the most when there was a monopolist firm.
Table 7: Size and Number of Transportation Firms

<table>
<thead>
<tr>
<th>Initial # of Firms</th>
<th># of Firms (% change)</th>
<th>Average Firm Size (% change)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.47</td>
<td>3.45</td>
</tr>
<tr>
<td>2</td>
<td>2.79</td>
<td>2.96</td>
</tr>
<tr>
<td>3</td>
<td>2.53</td>
<td>2.75</td>
</tr>
<tr>
<td>4+</td>
<td>2.29</td>
<td>2.50</td>
</tr>
</tbody>
</table>

5.2.2 Empirical Literature as a Baseline

We now compare our results with the standard methodologies used in the empirical literature as reported in Section 2.3.5. We used population as an instrument variable for the demand for transportation. The second column of Table 8 shows the declines in $\bar{p}$ generated by our model. Again, the largest decline takes place when there is one existing firm. As the number of existing shippers increases, the decline in transportation prices drops by more than half from 1.74 to 0.82%. In the third column we also see that the increase in trade flows also declines dramatically from 7.16 to 4.83%. The fourth column indicates that the implied elasticity of change $\bar{p}$ with respect to trade flows from our model.\footnote{A change in tariffs can be thought of as a right shift in the demand curve. Thus, if we compare the before and after trade flows and transportation prices, we can trace out the industry average cost curve.}

Our results are consistent with the strategy adopted by the empirical literature but add some additional insight. The reduced form results indicate that a 1% increase in trade leads to a 0.19% decline in prices. The results from the model show that the decline in transportation prices is not a constant 0.19% but depend critically on the number of existing firms. Thus, the elasticity implied by our model can be 25% higher or 10% lower. Furthermore, the elasticity captured by the reduced form estimates are closer to those ports with 3 or 4 firms, which is a very small portion of the ports in our sample. As shown in Figure 2.2, over 70% of ports in our sample have less than 2 transportation firms.
Table 8: Transportation Prices and Trade Flows

<table>
<thead>
<tr>
<th>Initial # of Firms</th>
<th>( \bar{p} ) (% chg)</th>
<th>Trade flows (% chg)</th>
<th>Elasticity Model</th>
<th>Elasticity IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-1.74</td>
<td>7.16</td>
<td>0.24</td>
<td>0.19</td>
</tr>
<tr>
<td>2</td>
<td>-1.43</td>
<td>5.84</td>
<td>0.24</td>
<td>0.19</td>
</tr>
<tr>
<td>3</td>
<td>-1.19</td>
<td>5.38</td>
<td>0.22</td>
<td>0.19</td>
</tr>
<tr>
<td>4+</td>
<td>-0.82</td>
<td>4.83</td>
<td>0.17</td>
<td>0.19</td>
</tr>
</tbody>
</table>

5.2.3 Constant Transporation Cost Model as a Baseline

Next, we compare the predictions of our model with one that has constant transporation prices. Table 9 compares the percent change in trade flows. The model with endogenous transportation costs predicts that markets with 1 shipper will see far greater increases than those with more shippers. In a monopolistic market, the increase in trade flows is 36\% more than what is predicted by a model in which transporation costs remain the same. As the number of shippers increases, the model with constant transportation costs converges to our model. Thus, the model with constant transportation costs correctly predicts trade flows for markets with a large number of existing firms and falls short in markets with one existing firm.

Table 9: Trade Flows After Liberalization

<table>
<thead>
<tr>
<th>Initial # of Firms</th>
<th>Constant ( \bar{p} ) (% change)</th>
<th>Endogenous ( \bar{p} ) (% change)</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.22</td>
<td>7.09</td>
<td>1.36</td>
</tr>
<tr>
<td>2</td>
<td>4.92</td>
<td>5.74</td>
<td>1.16</td>
</tr>
<tr>
<td>3</td>
<td>4.83</td>
<td>5.34</td>
<td>1.10</td>
</tr>
<tr>
<td>4+</td>
<td>4.61</td>
<td>4.83</td>
<td>1.05</td>
</tr>
</tbody>
</table>

The model with constant transportation costs fare worse in predicting welfare. Table 10 shows the average percent change in real income for the foreign country.\(^{26}\) Note that the welfare gains are small in percentage terms because this is the benefit due to decreasing tariffs by 1\% with one foreign port. In destinations with one shipper, a model with endogenous transportation costs will deliver 50\% more welfare gains from a liberalization. Even with 4

\(^{26}\)Foreign ports with 4+ shippers gain more from the trade liberalization because they have relatively larger trade with the foreign port as a fraction of GDP than the other ports.
and more shippers, this model delivers 8% more welfare gains.

Table 10: Real Income $f$ After Liberalization

<table>
<thead>
<tr>
<th>Initial # of Firms</th>
<th>Constant $\hat{p}$ (% change)</th>
<th>Endogenous $\hat{p}$ (% change)</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0013</td>
<td>0.0020</td>
<td>1.53</td>
</tr>
<tr>
<td>2</td>
<td>0.0012</td>
<td>0.0016</td>
<td>1.33</td>
</tr>
<tr>
<td>3</td>
<td>0.0025</td>
<td>0.0030</td>
<td>1.20</td>
</tr>
<tr>
<td>4+</td>
<td>0.0065</td>
<td>0.0070</td>
<td>1.08</td>
</tr>
</tbody>
</table>

Table 11 shows the percent change in real income for the home country. The home country loses in this trade reform due to the fact that it is lowering tariffs below its optimal level. The iceberg transportation cost model always overpredicts the losses that country $h$ faces. When there is a monopolist, the model with falling transportation costs predicts that losses will only be 15% of that predicted by the model with constant transportation costs. In the case with 4 or more shippers, the predictions of the two models become closer. The loss with falling transportation will only be 85% of that when they remain constant.

Table 11: Real Income $h$ After Liberalization

<table>
<thead>
<tr>
<th>Initial # of Firms</th>
<th>Constant $\hat{p}$ (% change)</th>
<th>Endogenous $\hat{p}$ (% change)</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-0.00005</td>
<td>-0.0000076</td>
<td>0.15</td>
</tr>
<tr>
<td>2</td>
<td>-0.00023</td>
<td>-0.000117</td>
<td>0.51</td>
</tr>
<tr>
<td>3</td>
<td>-0.00046</td>
<td>-0.0003057</td>
<td>0.66</td>
</tr>
<tr>
<td>4+</td>
<td>-0.00134</td>
<td>-0.0011440</td>
<td>0.85</td>
</tr>
</tbody>
</table>

6 Conclusion

The goal of this paper has been to show that features of the transportation industry have important implications for trade. Theoretically, we have embedded a model of the transportation industry in a model of trade. The model shows smaller transportation markets will have higher prices, fewer and smaller transportation firms. Furthermore, the model makes

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27 The optimal tariff for a country is increasing with its country size. In our average simulation, the home GDP is 14 times that of the foreign GDP. This implies that the optimal tariff for the home country will be very large. Irwin [1997] discusses the history of thought of the optimal tariff.
predictions about how quickly transportation prices decline as market size grows. Quantitatively, we have shown that a model in which transportation costs decline in response to a liberalization can have 50% more gains than one that does not.

This research has implications for policy: raising tariffs is particularly harmful for countries with small GDPs because they are penalized with higher transportation costs. Future research should focus on the implications of the large dispersion in freight prices that we observe that data. One interesting avenue is to think about how variations in prices account for the overall level of frictions that firms face when exporting.
References


