A Model of Trade with Endogenous Transportation Costs*

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Abstract

Fragmented connectivity is a reality of the transportation industry. Two ports need not be connected by a shipping line–in fact, the vast majority of ports in the world are not connected by a line. If this is the case, then any shipment must be off-loaded through at least one additional port adding expenses to the trip. In this paper, we examine the effect connectivity has on trade. We build a model of the transportation industry within a standard Melitz framework. To enter the transportation industry, firms must pay a fixed cost. Transportation firms also enjoy increasing returns to scale. Because of the fixed cost, small markets are less likely to be connected by a shipping line to another country. In addition, small markets that are connected will pay more because of market power of transportation firms and the inability to take advantage of economies of scale. In this model, trade volumes and transportation prices are jointly determined. The data set that we assembled on the route structure of the transportation industry and freight prices suggests that connectivity can significantly affect both the freight price and trade volume. We propose an estimation strategy using the data that we collected for the parameters of the transportation industry.

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1 Introduction

Using data that we assembled from the containerized maritime transportation industry[1], we show a series of facts about transportation prices. First, prices are lower if a destination port is connected by two or more shipping lines. Second, distance becomes statistically insignificant in a standard gravity equation once we control for whether the destination is connected by two or more lines. Third, prices are lower if the port is located in a country with a larger GDP.

In this paper we present a theory that can account for these empirical facts. We build a model of the transportation industry embedded within a standard Meltiz framework. In the model, shippers enjoy increasing returns to scale. In addition, they must pay a fixed cost to operate a line between two countries. Thus, small markets will pay more for transportation because they will not be directly connected to other countries. Small markets that are connected will pay more because of the market power of transportation firms and the their inability to take advantage of economies of scale. Explicitly modeling the transportation industry (and structurally estimating its parameters) is key because trade volumes and transportation prices are jointly determined.

This research contributes to the understanding of how route structure affect trade patterns. Almost no papers have dealt with the issue of endogeneity of transportation prices and the role of industry structure in determing price and trade volumes. This could explain why, for example the role of distance in gravity equation. We show that distance becomes statistically insignificant when we account for whether two ports are connected by a shipping line. This suggests that large drop offs in trade observed in gravity equations take place

[1]The vast majority of manufactured goods are transported internationally through containers. The container is a standardized metal container unit that can be transported on boats, trains, and trucks. The fact that it is standardized means that boats can be quickly loaded and unloaded, and can goods can be easily transported by various modes. The maritime transportation industry is also significiant. Hummels (2007) and Dalton (2011) find that around 80% of US imports of manufactured good take place through maritime transport.

because the probability of being connected by two or more lines decreases with distance. In addition, this research may have important implications for the welfare benefits of tariff reductions, since endogenous transportation prices enhance the effects of tariff reductions.

2 Literature Review

2.1 Trade Costs

Trade costs consist of all costs associated with getting a good to a final user. These costs include the cost of transporting a good, the time spent in transit, insurance, policy barriers (tariffs), information costs (finding clients), contract enforcements, costs associated with the use of different currencies, legal and regulatory costs, and local distribution costs (wholesale and retail).

Anderson and van Wincoop (2004) conducts a broad literature review of trade costs and concludes that trade costs are significant and there are still many open questions as to what determines them. They also point out that direct measures of trade costs are rare and often inaccurate. Indirect measures suggest that trade costs have declined over the last 50 years.

Other papers attempt to measure trade costs through by time using aggregate trade flows. Jacks et al. (2008) measure trade costs between the periods of 1870-2000 for France, UK and United States. They find that transportation prices have declined over this period. Waugh (2010) estimates trade frictions between rich and poor countries using bilateral trade volumes and price data. He finds that there are significant frictions between rich and poor countries.

Another set of papers investigates the impact of distance on trade flows and find that the role of distance is as important as ever, when measured as the coefficient of distance in the gravity equation. These papers include Berthelon and Freund (2008), Disdier and Head (2008), and Brun et al. (2005). They find that distance remains important in determining international trade: a 1% increase in distance is associated with a 1% decline in trade. These papers also find that the evolution of the distance coefficient in gravity equations has remained stable or may have risen through time. This fact is difficult to reconcile with empirical evidence that transportation costs have declined over this period. Allen (2011) attempts to understand why distance is important in gravity equations. He estimates a model with information and transportation costs using data from regional agricultural trade in the Philippines. He finds that search frictions can account for more than 90% of the decrease in trade as distance increases in the gravity equation.

2.2 Measuring Transportation Costs

Hummels (1999) and Hummels (2007) conduct a survey of the data on transportation costs. The first general conclusion that they make is that direct measures of trade costs are difficult to find and are often error-prone. For example, trade weighted measures of trade costs can be significantly biased downward. This is because consumers will substitute away from goods that have high transportation costs. Another commonly used measure of transportation prices is the differences between CIF (Cost, Insurance and Freight) and FOB (Free on Board) values from customs forms as published by the IMF. The difference between CIF and FOB is in theory the value of insurance and freight costs. However, Hummels and Lugovskyy (2006) show that these values are riddled with errors and contain no useful information for evolution of costs over time or comparing costs across commodities. The second broad conclusion of these surveys is that costs of transportation costs have declined over the last 50 years.

Other papers investigate the role of infrastructure in determining transportation costs and generally find that the quality of infrastructure is highly correlated to the trade costs and trade flows. These papers include Blonigen and Wilson (2006), Bougheas et al. (1999), Limao and Venables (2001), Moreira et al. (2008), Wilmsmeier et al. (2006), Clark et al. (2004), Wilson et al. (2003).

2.3 Endogenous Transportation Costs

Few papers dealt with the endogeneity of transportation prices and the effect on trade. Francois and Wooton (2001) study the effect of collusion in the maritime transportation industry and its effects on freight prices. Hummels et al. (2009) empirically estimate a similar model using Latin American data. They find that market power among transportation firms can play an important role in the price that countries pay for transportation.

3 Empirical Analysis

3.1 Description of Data – Freight Prices

Data on freight prices were obtained from Air Parcel Express (APX), a freight forwarder that acts as an intermediary between a shippers and exporting firms. The freight prices are for transporting a 20' container from Los Angeles[2] port to 258 different destination ports in August 2011. It is interesting to note that there is a large variance in the freight rates. The cheapest destination is Hong Kong where the freight cost is only $963. The most expensive destination is Guinea-Bissau where the freight cost is $7109.

3.2 Description of Data – Route Structure

We collected data about the route structure of the containerized liner service industry from Containerisation International. Containerisation International collects and sells data about containerized shipping. For each containerized shipping line, we collected data about 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 alliances (several firms jointly manage a line) that operate shipping lines.

[2]There are technically two adjacent ports: Los Angeles and Long Beach. We will treat these ports as one and refer to them as Los Angeles

The structure of container shipping is constituted of a great selection of routes, serviced by a collection of lines. A route is a series of ports that boats stop at. A very simple analogy is that of a bus system. A bus line follows a route. Two points can sometime be connected by one or more lines. However, sometimes there are no lines connecting two points, in which case a person must transfer at least once along the way. In the same way, maritime transportation is not always point-to-point and may involved unloading and loading a container along the way.

One feature of the data that is striking is the extent that the vast majority of ports in the world are not connected by a line. For example, of the 217 that we consider, Los Angeles has a line with only 27% of them. It is important to note that Los Angeles is one of the busiest container ports in the world.

In other words, sending a container to the vast majority of ports in the world involves unloading and loading at multiple ports along the way. Anecdotal evidence suggests that loading and unloading fees along with port taxes can substantially add to the cost of a trip.

3.3 Freight Prices in the Context of Route Structure

As a next step, want to to see how trade volume is related to the route structure of the transportation industry. We now estimate the following regression

$$\log(Price_i) = \alpha_0 + \alpha_1 \log(GDP_i) + \alpha_2 \log(Dist_i) + \beta_3 I\{RouteStructure\} + \epsilon_i$$

In the previous equation, i represents a destination port, GDP_i is the GDP of the country in which the destination port is located. $Dist_i$ is the distance from Los Angeles to the destination port measured in nautical miles.[3]

[3]We found this data using the online distance calculator offered by Sea Rates, a website that connects exporters to freight forwarders.

In the first column of Table 1, we see that GDP is statistically significant. This means that larger countries pay less for transportation. This is consistent with the idea that economies of scale are important in the transportation industry. In the second column, we see that distance by itself is not statistically significant by itself. However, in column three we see that distance is statistically significant once we take GDP of the destination port into account.

In column four, we include a dummy variable for whether the destination port is connected by a line. This dummy is statistically significant. Furthermore, the distance coefficient becomes insignificant. In column five, we include a dummy variable for whether the destination port is connected by 1 line or 2+ lines. We find that the dummy for 1 line is not statistically significant but the dummy for 2+ lines is statistically significant. The coefficient for distance remains statistically insignificant. The regression results indicate that ports that do not have 2+ lines pay 75% more than those ports that do. Los Angeles, one of the busiest ports in the world, is connected with 2+ lines with only 13% of the ports in our sample.

Table 1: Freight prices regression results

	Column 1	2	3	4	5
$\log(GDP_i)$	-0.081		-0.083	-0.069	-0.064
	(0.009)		(0.010)	(0.011)	(0.010)
$\log(Dist_i)$		0.086	0.141	0.056	-0.007
		(0.063)	(0.056)	(0.060)	(0.059)
I{1+ line}				-0.199	
				(0.058)	
I{1 line}					-0.035
					(0.066)
I{2+ lines}					-0.429
					(0.075)
R^2	0.217	0.008	0.232	0.270	0.333
n	229	229	229	229	229

Why is it that distance becomes insignificant when we control for the number of lines pass through the destination ports? This is because distance and the probability of having a line connecting another port is positive correlated. This can be seen in Table 2, which shows the connectivity for Los Angels. As the distance from Los Angeles increases, there is an increasing number of ports. In other words, as the radius of a circle increases, so will the circumference and the number of ports contained in the circle. For the case of Los Angeles, after 3,000 miles there is a strong drop off in connectivity. Of the 49 ports that are 9,000+ miles away, Los Angeles is connected to none of those ports by 2+ lines.

Table 2: International Connectivity for Los Angeles

Distance (miles)	Number of ports	% of ports with 1 lines	% of ports with 2+ lines
0-1,000	0	0	0
1-2,000	2	0	100
2-3,000	7	0	85
3-4,000	18	33	11
4-5,000	18	17	17
5-6,000	20	15	30
6-7,000	25	8	16
7-8,000	51	18	8
8-9,000	43	7	5
9,000+	49	6	0

3.4 Gravity Equation in the Context of Route Structure

As a next step, want to to see how trade volume is related to the route structure of the transportation industry. This is very similar to a gravity equation except that now trade volume is at a port level. We gathered data on containerized trade between Los Angeles and the foreign countries in our sample. We now estimate the following regression

$$\log(ContainerizedTrade_i) = \beta_0 + \beta_1 \log(GDP_i) + \beta_2 \log(Dist_i) + \beta_3 I\{RouteStructure\} + \epsilon_i$$

where $ContainerizedTrade_i$ is the total value of containerized trade between the destination country and Los Angeles.[4]

[4] Containerized trade data came from US Census's USA Trade Online database.

In column three of Table 3 that distance and GDP of the foreign country are both statistically significant. We note that the coefficients in column 3 are very similar to the traditional gravity equation. Column four shows that if we take connectivity into account then distance becomes statistically insignificant. Lastly, column five shows that only have 2+ lines connecting the destination port is statistically significant. This means that after controlling for GDP and distance, countries that are connected to Los Angels with 2+ lines have 7 times as much trade.[5]

Table 3: Value of containerized trade regression results

	Column 1	2	3	4	5
$\log(GDP_i)$	1.069		1.086	1.008	0.989
	(0.058)		(0.060)	(0.063)	(0.062)
$\log(Dist_i)$		-0.595	-1.112	-0.615	-0.391
		(0.503)	(0.322)	(0.347)	(0.351)
I{1+ line}				1.136	
				(0.331)	
I{1 line}					0.565
					(0.387)
I{2+ lines}					1.937
					(0.439)
R^2	0.585	0.006	0.598	0.619	0.631
n	229	229	229	229	229

4 Model

4.1 Consumer Problem

Consider a world with n. Let j represent an exporter and i represent an importer. Assume that country i is populated by identical consumers of measure $\bar{\ell}_i$. The representative consumer of country i takes prices, wages, and profits as given and solves the following

[5]If we raise both sides of the regression equation to e, we get that $ContainerizedTrade_i = e^{\beta_0} GDP_i^{\beta_1} Dist_i^{\beta_2} e^{\beta_3 I\{RouteStructure\}}$. Thus, having 2+ lines means that there will be $e^{\beta_3 I\{RouteStructure\}} = e^{1.937} = 6.94$ times as much trade.

problem

$$\max \left(\sum_{j=1}^{n} \int_{v\in\Omega_{ji}} c_{ji}(v)^{\frac{\sigma-1}{\sigma}} dv \right)^{\frac{\sigma}{\sigma-1}}$$

subject to

$$\sum_{j=1}^{n} \int_{v\in\Omega_{ji}} p_{ji}(v)c_{ji}(v)dv = w_i\bar{\ell}_i + \pi_{i,T} = R_i$$

where Ω_{ji} is the set of goods that is exported from country j to country i and $\pi_{i,T}$ is the profits from the transportation industry.

The solution to the consumer's problem is

$$c_{ji}(v) = \frac{R_i}{p_{ji}(v)^{\sigma} P_i^{1-\sigma}}$$

where

$$P_i^{1-\sigma} = \sum_{j=1}^{n} \left(\int_{v\in\Omega_{ji}} p_{ji}(v)^{1-\sigma} dv \right)$$

is the price index of country i.

4.2 Production Firm Problem

Firm v in country j pays fixed cost $w_j f_e$ to draw productivity ϕ from Pareto distribution with CDF $G(\phi) = 1 - \left(\frac{b}{\phi}\right)^{\beta}$. The firm has linear production function and pays fixed cost $w_j f$ to operate and $w_j f_{exp}$ to export. A firm in country j that enters market i faces the following pricing problem

$$\max p_{ji}(v)c_{ji}(v) - \frac{c_{ji}(v)}{\phi(v)} w_j \tau_{ji}(v)$$

The firms that enter the product market will set $p_{ji}(v) = \frac{\tau_{ji}}{\rho\phi(v)}$. Note that the pricing rule only depends on the firm's productivity. Thus, we can denote the pricing rule as $p_{ji}(\phi) = \frac{\tau_{ji}}{\rho\phi}$. We can denote profitability as $\pi_{ji}(\phi) = p_{ji}(\phi)c_{ji}(\phi) - \frac{c_{ji}(\phi)}{\phi}w_j\tau_{ji}(\phi)$. The minimum productivity necessary for a firm to operate, x_j, satisfies $\pi(x_j) = w_jf$. The minimum productivity necessary for firm from country j to export to country i is $\pi(y_{ji}) = w_jf_{exp}$.

The number of firms that draw, M_{ej}, is determined by the free entry condition

$$\bar{\pi}_j\left(1 - G(x_j)\right) = w_bf_e$$

$$\bar{\pi}_j = \sum_{i=1}^{n} \frac{\int_{y_{ji}}^{\infty} \pi_{ji}(\phi)dG(\phi)}{1 - G(y_{ji})}$$

The number of firms that operate, M_j, is determined by

$$M_{ej}\left(1 - G(x_j)\right) = M_j$$

The mass of exporters is from j to i, $M_{exp,ji}$, determined by

$$M_{exp,ji} = \left(1 - G(y_{ji})\right)M_{ej}$$

4.3 Transportation Firm Problem

The transportation industry is modeled as a two stage static entry game. In the first stage, M_{ji} discreet shippers enter the market to transport goods between country i and j by paying fixed cost F_{ji}. The marginal cost of shipping one unit of good v from j to i is $p_j(v)MC_{ji}(v)$ ($MC_{ji}(v)$ is in units of the good transported). In the second stage, firms compete a la Cournot to determine equilibrium quantity and price. We also assume that there is symmetry among shipping firms and that shipping firms are owned by country k.

For a given good v, shipping firm m takes as given aggregate prices, wages, and the quantity supplied by its $M_{ji}-1$ competitors and solves the following problem

$$\max_{q_{mji}(v)} (\tau_{ji}(v)-1)q_{mji}(v) - MC_{ji}(v)q_{mji}(v)$$

where $q_{mji}(v)$ is the amount of good v that is transported by firm m. Thus, $c_{ji}(v) = \sum_{m=1}^{M_{ji}} q_{mji}(v)$. We can rewrite the maximization problem as

$$\max_{q_{mji}(v)} \left(\left(\frac{1}{\sum_{m=1}^{M_{ji}} q_{mji}(v)} \frac{R_i}{p_j(v)^{\sigma} P_i^{1-\sigma}}\right)^{\frac{1}{\sigma}} - 1\right) q_{mji}(v) - MC_{ji}(v)q_{mji}(v)$$

since $\sum_{m=1}^{M_{ji}} q_{mji}(v) = c_{ji}(v) = \frac{R_i}{\tau_{ji}^{\sigma} p_j(v)^{\sigma} P_i^{1-\sigma}}$. The profit of transportation firm m that transports goods between country i and j is

$$\begin{aligned}\pi_{mji} = &\int_{v\in\Omega_{ji}} p_j(v)q_{mji}(v)\left(\tau_{ji}(v) - 1 - MC_{ji}(v)\right) dv \\ &+ \int_{v\in\Omega_{ij}} p_i(v)q_{mij}(v)\left(\tau_{ij}(v) - 1 - MC_{ij}(v)\right) dv\end{aligned}$$

Lastly, we impose a free entry condition (??)

$$\pi_{ji}(m) \leq F_{ji}$$

We assume symmetry among transportation firms and solve for the quantity supplied $q_{mji}(v)$ and $\tau_{ji}(v)$. We get that

$$\begin{aligned}q_{mji}(v) &= \frac{R_i}{p_j^{\sigma} P_i^{1-\sigma}} \frac{1}{M_{ji}} \left(\frac{\sigma M_{ji} - 1}{\sigma M_{ji}} \frac{1}{1 + MC_{ji}(v)}\right)^{\sigma} \\ \tau_{ji}(v) &= \frac{\sigma M_{ji}}{\sigma M_{ji} - 1}\left(1 + MC_{ji}(v)\right)\end{aligned}$$

Note that when $M_{ji} = 1$, the expression for price is the same as the standard monopolist markup over marginal cost. Also, as we approach perfect competition $M_{ji} = 1 \to \infty$, the markup approaches marginal cost. Every firm will carry a continuum of goods and M_{ij} is determined by the free entry condition.

4.4 Clearing Conditions

Impose balanced trade between each country pair i and j

$$\int_{v\in\Omega_{ji}} p_{ji}(v)c_{ji}(v)dv = \int_{v\in\Omega_{ij}} p_{ij}(v)c_{ij}(v)dv$$

and labor clearing condition in country j

$$\sum_{i=1}^{n}\int_{v\in\Omega_{ji}} \frac{c_{ji}(v)}{\phi(v)}dv + f_e M_{ej} + fM_j + f_{exp}\sum_{i=1}^{n} M_{exp,ji} = \bar{\ell}_j$$

5 Multiplicity of Equilibrium

As is typically the case in situations with increasing returns to scale, our model presents a wide range of equilibria even under the very simplest setups. We will show analytically how these situations arise in a symmetric two country model. We will also perform comparative statics on this simple setup to show that, assuming countries stay in the same equilibrium, larger markets pay less for transportation because of the reduced market power of shipping firms and the fact that they enjoy the benefits of economies of scale.

5.1 Two Country Example

We will now analytically show how multiplicity can arise in a very simple setup with two symmetric countries. For simplicity, we will assume that there is a continuous number of shippers and that the zero profit condition (ZPC) holds. Normalize $w = 1$.

It can be shown that the following equations characterize the equilibrium objects x, y, M, m_{exp}, $\bar{\pi}$, M_{exp}, M_e, R, P

$$\frac{R}{P^{1-\sigma}}\left(\frac{\sigma}{\sigma-1}\frac{1}{x}\right)^{1-\sigma} = \sigma f \tag{5.1}$$

$$\frac{R}{P_S^{1-\sigma}}\left(\frac{\sigma}{\sigma-1}\frac{1}{y}\tau\right)^{1-\sigma} = \sigma f_{\text{exp}} \tag{5.2}$$

$$\bar{\pi}\left(1-G(x)\right) = f_e \tag{5.3}$$

$$m_{\text{exp}} = \frac{1-G(y)}{1-G(x)} \tag{5.4}$$

$$\bar{\pi} = wf\left(\frac{\beta}{\beta+1-\sigma}-1\right) + m_{\text{exp}}f_{\text{exp}}\left(\frac{\beta}{\beta+1-\sigma}-1\right) \tag{5.5}$$

$$M_{\text{exp}} = m_{\text{exp}}M \tag{5.6}$$

$$M_e = \frac{M_B}{(1-G(x))} \tag{5.7}$$

$$R = \bar{\ell} \tag{5.8}$$

$$P^{1-\sigma} = \frac{\beta}{\beta+1-\sigma}M\left(\frac{\sigma-1}{\sigma}x\right)^{\sigma-1} + \frac{\beta}{\beta+1-\sigma}M_{\text{exp}}\left(\frac{\sigma-1}{\sigma}\frac{1}{\tau}y\right)^{\sigma-1} \tag{5.9}$$

We wil first solve for M. By combining equations 5.1, 5.2, and 5.9 we get that

$$1 = \frac{\beta}{\beta+1-\sigma}\frac{\sigma}{\bar{\ell}}\left(Mf + M_{\text{exp}}f_{\text{exp}}\right)$$

We combine this expression with equations 5.4, 5.6, and again 5.1, and 5.2, we get that

$$M = \frac{\beta+1-\sigma}{\beta}\frac{\bar{\ell}}{\sigma}\frac{1}{f+\tau^{-\beta}f^{\frac{\beta}{\sigma-1}}f_{\text{exp}}^{1+\frac{-\beta}{\sigma-1}}} \tag{5.10}$$

We now solve for P. If we combine equations 5.3, 5.4, and 5.5 we get that

$$\left(\frac{\beta}{\beta+1-\sigma}-1\right)\left(\left(1-G(x)\right)f+\left(1-G(y)\right)f_{\mathrm{exp}}\right)=f_e$$

We combine this expression with 5.1, and 5.2, and we get that

$$P=\frac{1}{b}\left(\frac{\sigma}{\sigma-1}\left(\frac{\sigma}{\bar{\ell}}\right)^{\frac{1}{\sigma-1}}\right)\left(\frac{f_e}{\left(f^{1-\frac{\beta}{\sigma-1}}+f_{\mathrm{exp}}^{1-\frac{\beta}{\sigma-1}}\tau^{-\beta}\right)}\frac{1}{\left(\frac{\beta}{\beta+1-\sigma}-1\right)}\right)^{\frac{1}{\beta}} \tag{5.11}$$

Finally, we can solve for M_{exp}. Combine equations 5.1, 5.2, 5.4, 5.6, and 5.10 and we get that

$$M_{\mathrm{exp}}=\left(\frac{f}{f_{\mathrm{exp}}}\right)^{\frac{\beta}{\sigma-1}}\tau^{-\beta}\frac{\beta+1-\sigma}{\beta}\frac{\bar{\ell}}{\sigma}\frac{1}{f+\tau^{-\beta}f^{\frac{\beta}{\sigma-1}}f_{\mathrm{exp}}^{1+\frac{-\beta}{\sigma-1}}} \tag{5.12}$$

From the transportation industry, we get that

$$\tau=F\frac{1}{2M_{\mathrm{exp}}\sigma f_{\mathrm{exp}}}\frac{\beta+1-\sigma}{\beta}+1+MC \tag{5.13}$$

If we combine equations 5.12 and 5.13 we get that

$$-F\frac{1}{\bar{\ell}}\frac{1}{2}\frac{f}{f_{\mathrm{exp}}}\tau^{\beta}+\tau-F\frac{1}{\bar{\ell}}\frac{1}{2}-1-MC=0$$

This equation can have multiple solutions depending on the value of the parameters and β.

6 Econometric model

6.1 Deriving the Profit Function

We know from the profit function of a transportation firm we can get that

$$\pi_{mji} = 2\frac{(\tau_{ji} - 1 - MC_{ji})}{M_{ji}\tau_{ji}} M_{\exp ji} \frac{\beta}{\beta + 1 - \sigma} \sigma w_j f_{\exp} - F_{ji}$$

This can simplified to

$$\pi_{mji} = 2\frac{TVT_{ji}}{\sigma M_{ji}^2} - F_{ji}$$

where TVT_{ji} is the total value of trade from country j to country i.

For our empirical analysis, we assume that the profit function has the following form

$$\pi_{mji} = 2\frac{TVT_{ji}}{\sigma M_{ji}^2} - F_{ji} + \xi_{mji} \tag{6.1}$$

where ξ_{mji} is extreme value iid.

6.2 Estimation strategy

We can now use equation 6.1 to estimate the fixed cost of serving a destination port. Because ξ_{mji} is extreme value iid, this means that the probability p of a shipping firm servicing a route is

$$\frac{e^{2\frac{TVT_{ji}}{\sigma M_{ji}^2} - F_{ji}}}{1 + e^{2\frac{TVT_{ji}}{\sigma M_{ji}^2} - F_{ji}}}$$

Suppose that we observe in the data that there are N number of firms that are active on a particular route and that n shippers make a stop at a particular port. We can write the likelihood function as

$$\mathcal{L} = n \log\left(\frac{e^{2\frac{TVT_{ji}}{\sigma M_{ji}^2} - F_{ji}}}{1 + e^{2\frac{TVT_{ji}}{\sigma M_{ji}^2} - F_{ji}}}\right) + (N - n) \log\left(\frac{1}{1 + e^{2\frac{TVT_{ji}}{\sigma M_{ji}^2} - F_{ji}}}\right)$$

we maximize over the values of F_{ji}. Furthermore, we can now perform counterfactuals as to what would happen if some underlying paramter changes.

7 Conclusion

The goal of this paper has been to show that the route structure of the transportation industry has important implications for trade. No other papers in the literature have attempted to structurally estimate the transportation industry within the context of a trade model. We have developed a model that predicts that small countries will pay more for transportation because they are less likely to be connected by a line to another country. Even if there is a line, because of the lack of volume the country might be serviced by a monopolist and a firm that cannot take full advantage of economies of scale.

This paper provides the first step to understanding the implication of endogenous transportation costs on trade flows.

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