

# The Round Trip Effect: Endogenous Transport Costs and International Trade

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## Abstract

Ocean containerships transport the bulk of international trade flows and travel in fixed round trip routes. This paper studies this round trip effect, which links two-way transport supply between locations. I show that this effect mitigates shocks on one-direction trade and generates opposite-direction spillovers with the same partner. Import tariff increases can therefore translate into potential export taxes. I develop an IV using this effect to estimate a containerized trade elasticity. Using these results, I estimate and simulate a counterfactual import tariffs increase. My model predicts a 0.2% export price tax when doubling US import tariffs from a 1.2% average.

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# 1 Introduction

*“If transport costs varied with volume of trade, the [iceberg transport costs] would not be constants. Realistically, since there are joint costs of a round trip, [the going and return iceberg costs] will tend to move in opposite directions, depending upon the strengths of demands for east and west transport.”*

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Samuelson (1954), p. 270, fn. 2

The cost of transporting goods from origin to destination is determined in equilibrium by the interaction between the supply and demand for transportation between these locations. Additionally, carriers, such as containerships and airplanes, travel in fixed routes and have to return to the origin in order to fulfill demand (Pigou and Tausig (1913), Demirel, Van Ommeren and Rietveld (2010)). In practice, this constrains carriers to a round trip and introduces joint transportation costs which links transport supply bilaterally between locations on major routes (*the round trip effect*). One example is the US-China route currently serviced by Maersk, the largest containership company globally, where the ships travel exclusively between the ports of Yantian and Ningbo in China, as well as Long Beach (figure 1).

As a result, asymmetric demand between locations translates into asymmetric transport costs. China runs a large trade surplus with the United States, and the cost to ship a container from China to the US (\$1900 per container) is more than three times the return cost (\$600 per container).<sup>1</sup> The US and UK, who have relatively more balanced trade with each other, have more similar container costs (\$1300 per container from UK to US compared to the return cost of \$1000 per container). Not just unique to container shipping, the round trip effect also applies to air cargo and US domestic trucking.<sup>2</sup> Figure 2 shows that the gap in containerized trade value to and from a pair of countries, which approximates the trade demand asymmetry between countries, is positively correlated with the gap in the cost of containers going to and from these countries. This relationship can also be established with container volumes (figure A.1).

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<sup>1</sup>2013 container freight rates from Drewry Maritime Research.

<sup>2</sup>The cost to ship air cargo from China to US is ten times more than the return cost (\$3-\$3.50 per kg from China to US compared to 30-40 cents per kg on the return; Behrens and Picard (2011)). Within the US domestically, it costs two times more to rent a truck from Chicago to Philadelphia than the return (\$1963 at \$2.69 per mile from Chicago to Philadelphia compared to \$993 at \$1.31 per mile for the return; DAT Solutions).

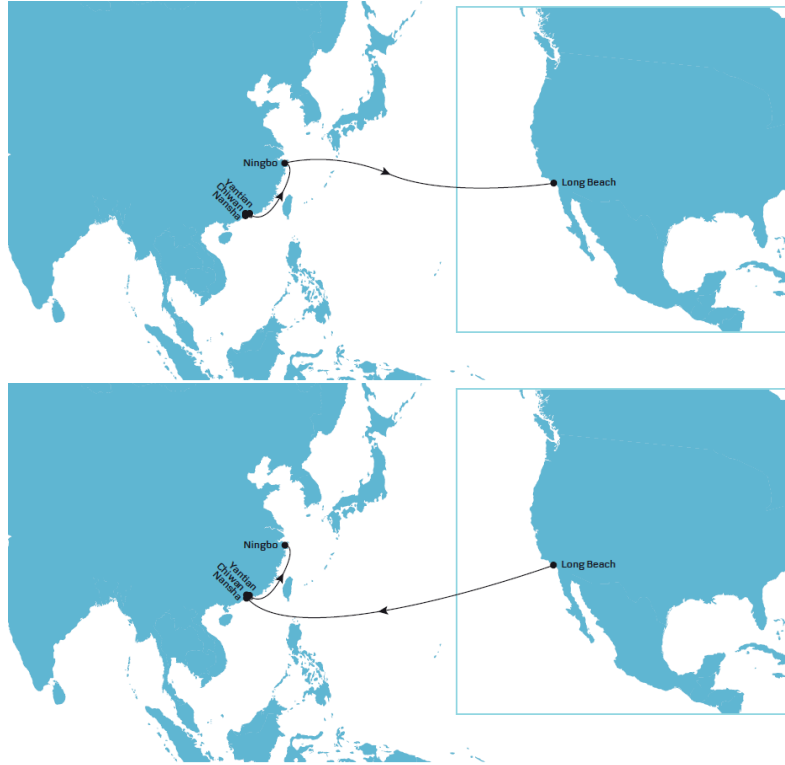


Figure 1: An example of the round trip effect: Containership route between US and China

Note: Land is shaded blue. Source: Maersk East-West Network, TP3 Service. The top panel indicates the eastbound service. The containership departs from Yantian on a Tuesday, Ningbo on a Thursday two days later, and arrives in Long Beach the following Wednesday after 12 days. Two days later (Friday), it departs from Long Beach and return to Ningbo and Yantian on the westbound service (the bottom panel). The announcement of exact arrival/departure days for each port is also commonly done by other containership companies as part of their fixed route schedules.

The principal contribution of this paper is to provide a microfoundation for transport costs which incorporates one of its key institutional features, the round trip effect. This paper is the first, to my knowledge, to study both the theoretical and empirical implications of the round trip effect for trade outcomes. Transport costs in the trade literature are typically modeled as exogenous. They are typically approximated by distance empirically and by the iceberg functional form theoretically.<sup>3</sup> From the previous example, container freight rates between US and China would be the same or close to being symmetric if they were predominantly determined by distance. However, this is not the case nor is it the case for other countries as well (figure 2). Even as he introduced the notion of iceberg transport costs to the literature, Samuelson (1954) acknowl-

<sup>3</sup>Exceptions include Donaldson (Forthcoming), Asturias and Petty (2013), Friedt and Wilson (2015), Hummels, Lugovskyy and Skiba (2009), and Irarrazabal, Moxnes and Opromolla (2015).

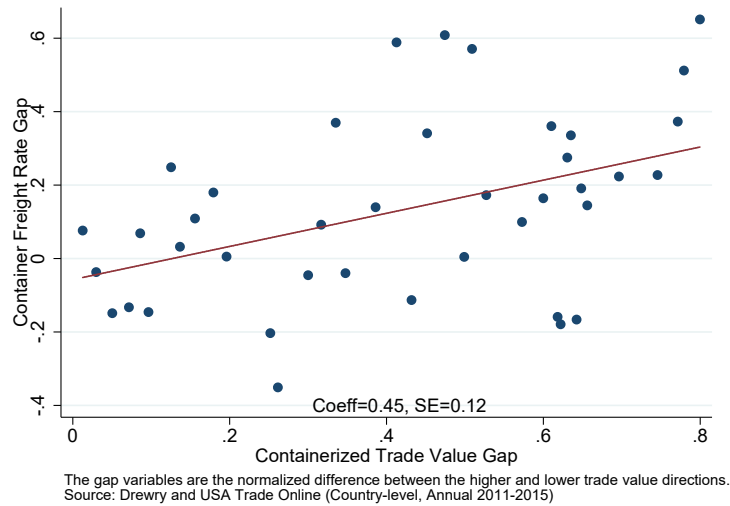


Figure 2: Containerized trade value gap is positively correlated with container cost (freight rate) gap between countries

edged that in the realistic presence of joint costs of a round trip, the iceberg transport costs between locations will move in opposite directions depending on both demand strengths. I provide evidence of this inverse relationship using a novel port-level data set on container freight rates.

In order to study the trade implications from the round trip effect, I build an Armington trade model which incorporates this feature of the transportation industry. I show two main differences between my model and a model with exogenous transport costs. First, the trade impact of any demand or supply shocks for the underlying goods will be mitigated by an endogenous transport costs movement along the same directional route. This impact is present as a result of endogenous transport costs. Second, the round trip effect adds the spillover effect of these shocks on the reverse direction of trade with the same partner. For example, a unilateral increase in US tariffs on imports from China would not just result in a decrease in US imports from China (the magnitude of which is mitigated by a fall in US import transport cost from China) but also a decrease in US exports to China. This export decrease is due to an increase in the US export transport cost to China since less ships will come to the US due to the fall in the opposite direction (China to US) trade demand.

Through the round trip effect, an import tariff on a country's partner can therefore also translate into an export tax on the same partner. Lerner symmetry (Lerner (1936)) predicts that a country's unilateral tariff increase on one partner will act as an export tax

and reduce its exports to all its partners due to the balanced trade condition in a general equilibrium setting. I present a specific *bilateral* channel that impacts the country's exports to the same partner within a partial equilibrium framework, without requiring the balanced trade condition.<sup>4</sup>

I provide suggestive evidence for two main predictions from my trade and transport model using a proprietary data set on port-level container freight rates matched to containerized trade data. First, freight rates within port pairs are negatively correlated across time and within routes. This inverse relationship is predicted in my model due to transport firms optimizing over a round trip. As such, the transport costs in each direction of the port pair route will move in opposing directions in response to demand changes across time. If freight rates were independently determined in each direction of a port pair, one would expect there to be no correlation. In addition, if freight rates were mostly determined by distance, one would also expect no correlation since route fixed effects are included in my regressions. Second, outgoing containerized trade value is positively correlated with incoming freight rates across time and within dyads. This applies to incoming trade value and outgoing freight rates as well. This relationship would not be present if there was no systematic linkage between aggregate outgoing containerized trade value and the incoming freight rates. The round trip effect provides one such explanation.

Next, I estimate the containerized trade elasticity with respect to freight rates using the round trip insight. Since containers are required to transport containerized trade, this elasticity can also be interpreted as the demand elasticity for containers. In typical demand estimations, I require a transport supply shifter that is independent of demand determinants. In the example of estimating containerized trade demand from UK to US, I need a shifter of transport supply from UK to US that is independent of the demand determinants on the same route. I develop a novel supply shifter utilizing the round trip effect: shocks which affect the opposite direction containerized trade (from US to UK). These shocks will shift both its own container transport supply as well as the transport supply in the original direction (from UK to US). This latter transport supply shift will identify the containerized trade demand from UK to the US if the demand shocks between routes are uncorrelated. Since demand shifts between countries are generally not independent, I construct a Bartik shift-share instrument that approximates

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<sup>4</sup>My findings are in line with Costinot and Werning (2017) who show that trade balance is not a necessary or sufficient condition for the Lerner Symmetry to hold.

this transport supply shift. I find that a one percent increase in container freight rates leads to a 2.8 percent decrease in containerized trade value, 3.6 percent decrease in trade weight, and a 0.8 percent increase in trade value per weight. Since trade value per weight can be interpreted as a rough measure of trade quality, my third result is in line with the positive link between quality and per unit trade costs first established by Alchian and Allen (1964).

Using my trade elasticity estimated from the instrumental variable approach, I estimate parameters in my transportation and trade model by matching the observed freight rate and trade data. I then simulate a counterfactual in which US doubles its tariffs on all its partners from an overall trade weighted average of 1.16 percent. I show that the rise in the US tariff will both decrease US imports from these partners and decrease US exports to these partners. I show that the same model with exogenous transport costs would over-predict the average import decrease by 41 percent, not predict any export decrease, and under-predict the total trade changes by an average of 25 percent. Overall, increasing US import tariffs by a factor of one will result in a constant 0.2 percent tax on export prices.

This paper contributes to several strands of literature. First, it is broadly related to the literature which studies how trade costs affect trade flow between countries (Anderson and Van Wincoop (2004), Eaton and Kortum (2002), as well as Head and Mayer (2014)). In particular, I focus on the literature on transport cost (Hummels (2007) and Limao and Venables (2001)) and highlight a feature of the transportation industry—the round trip effect—using a novel high frequency data set on bilateral freight rates. Previous theoretical studies on the round trip effect investigates how it affects the spatial distribution of firms (Behrens and Picard (2011)) and the potential harmful impact from domestic import restrictions on exports (Ishikawa and Tarui (2016)). The theory model in this paper builds on Behrens and Picard (2011). Previous empirical studies on the round trip effect typically employs aggregate data sets at the regional level (Friedt and Wilson (2015)) or within a country at the annual frequency (Tanaka and Tsubota (2016) and Jonkeren et al. (2011))<sup>5</sup>. My data is at the monthly frequency, the port-level in both directions, and includes the largest ports globally. This high level of disaggre-

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<sup>5</sup>Tanaka and Tsubota (2016) estimates the effects of trade flow imbalance on transport price ratio between Japanese prefectures. Focusing on 3 regions (US, Asia, and Europe), Friedt and Wilson (2015) evaluate the impact of freight rates on dominant and secondary routes. Jonkeren et al. (2011) focuses on dry bulk cargo in the inland waterways of the Rhine. Friedt (2017) studies the impact of commercial and environmental policy on US-EU bilateral trade flows in the presence of the round trip effect.

gation allows me to better study the round trip effect and its trade implications. I am also able to exploit the panel nature of this data set in my empirical estimations.

Second, this paper develops a novel IV strategy using an institutional detail of the transportation industry in order to estimate a transport mode-specific trade elasticity with respect to transport cost. This is the first paper to do so. Previous studies have typically focused on trade elasticities across all transport modes (e.g. Head and Mayer (2014), Shapiro (2015)) and my elasticity contributes to understanding how trade elasticities respond to transport costs within a mode, i.e. container shipping. Additionally, the round trip effect applies to the transportation industries servicing both international and domestic trade. As such, endogenous transport costs may have an important contribution to the spatial allocation of production in and across countries. My IV strategy can be utilized to identify this.

This paper is also related to empirical literature on endogenous transport costs. My theory model builds on Hummels, Lugovskyy and Skiba (2009) by introducing the round trip effect feature in the transport firms framework. Hummels, Lugovskyy and Skiba (2009) investigates the role of market power on transport prices using US and Latin American imports data.<sup>6</sup> Focusing on dry bulk ships, Brancaccio, Kalouptsi and Papageorgiou (2017) studies endogenous transport costs in the presence of search frictions between exporters and transport firms. Hummels and Skiba (2004) investigates the relationship between per unit trade cost and product prices. Third, this paper is related to studies on containerization and trade. Cosar and Pakel (2017) studies the effects of containerization on transport by looking at the choice between containerization and breakbulk shipping. Bernhofen, El-Sahli and Kneller (2016) estimates the effects of containerization on world trade while Rua (2014) investigates the diffusion of containerization.

In the next section, I incorporate a transportation market into an Armington model. I present the comparative statics from trade shocks in my model and compare them to outcomes from an exogenous transport cost model. In section 3, I introduce my novel data set on port-level container freight rates matched to containerized trade data and establish suggestive evidence for two predictions in my theory model. I develop an instrument based on the round trip effect insight in section 4 to address endogeneity between transport cost and trade. I highlight my results in section 5. In section 6, I

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<sup>6</sup>Other studies that focus on market power within the transport sector include Asturias and Petty (2013) and Francois and Wooton (2001).

utilize my trade elasticity from section 5 to estimate parameters in my theory model in section 2 in order to match the observed trade and freight rates data. I then simulate a counterfactual increase in US import tariffs on all its partners. I compare the trade predictions from my model to a model with exogenous transport cost. Section 7 concludes.

## 2 Theoretical Framework

This section presents the theoretical implications of endogenous transport costs and the round trip effect in an Armington trade model. To highlight the impact of the round trip effect on the model, I start by solving the model under the assumption that transport costs are exogenous and then incorporate a transport sector with the round trip effect. I then describe the comparative statics between the two models. Appendix section [A.1](#) presents a graphical illustration of the round trip effect and its mechanism using a simple linear transport demand and supply model.

The trade model in this paper is a modification of Hummels, Lugovskyy and Skiba (2009) to incorporate the round trip effect and to allow for heterogeneous countries. To maintain simplicity in a first pass of modeling the round trip effect, I assume perfectly competitive transport firms. The main results here do not hinge on this assumption.

### 2.1 Model Setup

The world consists of  $j = 1, 2, \dots, M$  potentially heterogeneous countries where each country produces a different variety of a tradeable good. Consumers consume all varieties of this tradeable good from all countries as well as a homogeneous numeraire good. The utility function of a representative consumer in country  $j$  is quasilinear:

$$U_j = q_{j0} + \sum_{i=1}^M a_{ij} q_{ij}^{(\sigma-1)/\sigma}, \quad \sigma > 1 \quad (1)$$

where  $q_{j0}$  is the quantity of the numeraire good consumed by country  $j$ ,  $a_{ij}$  is  $j$ 's preference parameter for the variety from country  $i$ ,  $q_{ij}$  the quantity of variety from  $i$  consumed  $j$ , while  $\sigma$  is the price elasticity of demand. The numeraire good is costlessly traded and its price is normalized to one.

Assuming that each country is perfectly competitive in producing their variety and that labor is the only input to production, the delivered price of country  $i$ 's good in  $j$  ( $p_{ij}$ ) reflects its delivered cost which includes  $i$ 's domestic wages ( $w_i$ ), the ad-valorem



tariff rate that  $j$  imposes on  $i$  ( $\tau_{ij} \geq 1$ ), and a per unit transport cost ( $T_{ij}$ ):

$$p_{ij} = w_i \tau_{ij} + T_{ij} \quad (2)$$

## 2.2 Exogenous transport cost model

The cost of transport here is an exogenously determined one-way marginal cost of shipping ( $c_{ij}$ ). The delivered price of country  $i$ 's good in  $j$  ( $p_{ij}^{Exo}$ ) is then:

$$p_{ij}^{Exo} = w_i \tau_{ij} + c_{ij} \quad (3)$$

An increase in the marginal cost of transport ( $c_{ij}$ ),  $j$ 's tariff on  $i$  ( $\tau_{ij}$ ), or wages in  $i$  ( $w_i$ ) will increase the equilibrium price of  $i$ 's good in country  $j$ . Following Behrens and Picard (2011) and Hummels, Lugovskyy and Skiba (2009), one unit of transport services is required to ship one unit of good.

The utility-maximizing quantity of  $i$ 's good consumed in  $j$  ( $q_{ij}^{Exo}$ ) is derived from the condition that the price ratio of  $i$ 's good relative to the numeraire is equal to the marginal utility ratio of that good relative to the numeraire.<sup>7</sup> The equilibrium trade value of  $i$ 's good in  $j$  ( $X_{ij}^{Exo}$ ) is the product of the delivered price ( $p_{ij}^{Exo}$ ) and quantity ( $q_{ij}^{Exo}$ ) on route  $ij$ :

$$q_{ij}^{Exo} = \left[ \frac{\sigma}{\sigma - 1} \frac{1}{a_{ij}} (w_i \tau_{ij} + c_{ij}) \right]^{-\sigma} \quad (4)$$

$$X_{ij}^{Exo} \equiv p_{ij}^{Exo} q_{ij}^{Exo} = \left[ \frac{\sigma}{\sigma - 1} \frac{1}{a_{ij}} \right]^{-\sigma} [(w_i \tau_{ij} + c_{ij})]^{1-\sigma}$$

An increase in  $j$ 's preference for  $i$ 's good ( $a_{ij}$ ) will increase both the equilibrium quantity and value. On the other hand, an increase in  $i$ 's wages,  $j$ 's import tariff on  $i$ , and the transport marginal cost will decrease both.

## 2.3 Endogenous transport cost and the round trip effect

Here transportation is endogenized with the round trip effect. The profit function of a perfectly competitive transport firm servicing the round trip between  $i$  and  $j$  ( $\pi_{ij}^{\leftrightarrow}$ )

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<sup>7</sup>From equation (4),  $\sigma$  is the price elasticity of demand:  $\frac{\partial q_{ij}^{Exo}}{\partial p_{ij}^{Exo}} \frac{p_{ij}^{Exo}}{q_{ij}^{Exo}} = -\sigma$ . This equilibrium quantity differs from a standard CES demand because it is relative to the numeraire rather than relative to a bundle of the other varieties. If this model is not specified with a numeraire good, this quantity expression would include a CES price index that is specific to each country (in this case country  $j$ ). I follow Hummels, Lugovskyy and Skiba (2009) in controlling for importer fixed effects in my empirical estimates. This fixed effect can be interpreted as the price of the numeraire good or as the CES price index in the more standard non-numeraire case. Stemming from this, the balanced trade condition between countries is satisfied by the numeraire good.

is based on Behrens and Picard (2011):

$$\pi_{ij} = T_{ij}q_{ij} + T_{ji}q_{ji} - c_{ij} \max\{q_{ij}, q_{ji}\} \quad (5)$$

$q_{ij}$  is the quantity of goods shipped from  $i$  to  $j$  on route  $ij$  while  $c_{ij}$  is the marginal cost of serving the round trip between  $i$  and  $j$  like the cost of hiring a captain or renting a ship. While this cost function does not include one-way expenses like loading or unloading costs and fuel, it would not change the main results to include them. Following Behrens and Picard (2011) and Hummels, Lugovskyy and Skiba (2009), one unit of good is moved using one unit of transport services.

While the perfect competition assumption here is mostly to maintain simplicity, persistent over-capacity and introduction of pro-competitive policies in the container shipping industry contribute to the basis for this assumption. There has recently been persistent over-capacity in the container shipping industry, up to as much as 30 percent more space on ships than cargo, which can contribute to the 2016 bankruptcy of the world's seventh-largest container shipping line.<sup>8</sup> This period of over-capacity coincides with the period of my data sample. Moreover, while past enforcement of price-setting conference rates on global routes were possible because member contract rates were publicly available, the Shipping Act of 1984 limited the amount of information available on these contracts and The Ocean Shipping Reform Act of 1998 made them confidential altogether. Conference members are now able to deviate from conference rates without repercussion. As such, I conclude that transport firms can be reasonably approximated by perfect competition particularly during my sample period.

There are two possible equilibrium outcomes from this model depending on the relative demand between countries. The first equilibrium is an interior solution where the transport market is able to clear at positive freight rates in both directions and the quantity of transport services are balanced between the countries. The second equilibrium is a corner solution where one market is able to clear at positive freight rates while the opposite direction market has an excess supply of transport firms. The transport freight rate of the excess supply direction is zero. The absence of zeros in the freight rates data suggests that the first equilibrium is more relevant and hence is the focus here. While not all containers are at capacity on all routes, a Miao (2006) search model for transport firms and exporting firms using Chaney (2008) yields the same predictions.<sup>9</sup>

<sup>8</sup>Review of Maritime Transport, UNCTAD. South Korean Hanjin Shipping, [The Wall Street Journal](#), Sept 2016.

<sup>9</sup>See online appendix B for the search model.

### 2.3.1 Optimality conditions

From the profit function of transport firms in (5), the optimal freight rates on route  $ij$  and return route  $ji$  will add up to equal the marginal cost of the round trip between  $i$  and  $j$ :

$$T_{ij} + T_{ji} = c_{ij}^{\leftrightarrow} \quad (6)$$

which implies that the freight rates between  $i$  and  $j$  are negatively correlated with each other conditional on the round trip marginal cost  $c_{ij}^{\leftrightarrow}$ .

From utility-maximizing consumers in (1) and profit-maximizing manufacturing firms in (2), the optimal trade value of country  $i$ 's good in  $j$  as follows:

$$X_{ij} = \left( \frac{\sigma}{\sigma-1} \frac{1}{a_{ij}} \right)^{-\sigma} (w_i \tau_{ij} + T_{ij})^{1-\sigma}, \quad \sigma > 1 \quad (7)$$

It is decreasing in wages in  $i$ ,  $j$ 's import tariffs on  $i$ , and the transport cost from  $i$  to  $j$ .

Combining both the optimality conditions for freight rates between  $i$  and  $j$  in (6), as well as the relationship between trade value and freight rates in (7), the trade value of country  $i$ 's good in  $j$  is positively correlated with the return direction freight rates from  $j$  to  $i$ :

$$X_{ij} = \left( \frac{\sigma}{\sigma-1} \frac{1}{a_{ij}} \right)^{-\sigma} (w_i \tau_{ij} + c_{i,j} - T_{ji})^{1-\sigma}, \quad \sigma > 1 \quad (8)$$

Absent the round trip effect, a systematic relationship between a country's imports from a particular partner and its export transport cost to the same partner would not be typically expected. The same applies to a country's exports and its import transport cost with the same partner.

### 2.3.2 Equilibrium with endogenous transport cost and the round trip effect

The equilibrium freight rate for route  $ij$  under the round trip effect ( $T_{ij}^R$ ) can be derived from the market clearing condition for transport services:

$$T_{ij}^R = \frac{1}{1+A_{ij}} (c_{ij}^{\leftrightarrow}) - \frac{1}{1+A_{ij}^{-1}} (w_i \tau_{ij}) + \frac{1}{1+A_{ij}} (w_j \tau_{ji}), \quad A_{ij} = \frac{a_{ji}}{a_{ij}} \quad (9)$$

where  $A_{ij}$  is the ratio of preference parameters between  $i$  and  $j$ . The first term shows that the freight rate from  $i$  to  $j$  is increasing in the marginal cost of servicing the round trip route ( $c_{ij}^{\leftrightarrow}$ ). The second term shows that it is decreasing with the destination country  $j$ 's import tariff on  $i$  ( $\tau_{ij}$ ) and origin  $i$ 's wages ( $w_i$ ). The third term, due to the round trip effect, shows that the freight rate is increasing in the origin country  $i$ 's import tariff on  $j$  ( $\tau_{ji}$ ), as well as destination  $j$ 's wages ( $w_j$ ). The second term provides a mitigating effect on the changes in trade demand or supply on route  $ij$  while the third term provides the

same mitigating effect but for changes on the opposite route  $ji$ .<sup>10</sup>

The equilibrium price of country  $i$ 's good in  $j$  is increasing in the marginal cost of round trip transport  $c_{ij}^{\leftrightarrow}$ , as well as the wages and import tariffs in both countries. This price is a function of  $j$ 's own wages and the import tariff it faces from  $i$  is due to the round trip effect:

$$p_{ij}^R = \frac{1}{1 + A_{ij}} \left( w_j \tau_{ji} + w_i \tau_{ij} + c_{ij}^{\leftrightarrow} \right), \quad A_{ij} = \frac{a_{ji}}{a_{ij}} \quad (10)$$

The equilibrium trade quantity and value on route  $ij$  are decreasing in the marginal cost of transport, both countries' wages and import tariffs:<sup>11</sup>

$$\begin{aligned} q_{ij}^R &= \left[ \frac{\sigma}{\sigma - 1} \frac{1}{a_{ij}} \frac{1}{1 + A_{ij}} \left( w_j \tau_{ji} + w_i \tau_{ij} + c_{ij}^{\leftrightarrow} \right) \right]^{-\sigma} \\ X_{ij}^R &= \left[ \frac{\sigma}{\sigma - 1} \frac{1}{a_{ij}} \right]^{-\sigma} \left[ \frac{1}{1 + A_{ij}} \left( w_j \tau_{ji} + w_i \tau_{ij} + c_{ij}^{\leftrightarrow} \right) \right]^{1-\sigma}, \quad A_{ij} = \frac{a_{ji}}{a_{ij}} \end{aligned} \quad (11)$$

These equilibrium outcomes are due to the round trip effect: a country's imports and exports to a particular trading partner are linked through transportation. For example, when country  $i$  increases its import tariff on country  $j$  ( $\tau_{ji}$ ), not only will its own imports from  $j$  be affected, but its exports to  $j$  as well (equation (11)). The comparative statics section below elaborates.

## 2.4 Comparative statics

This subsection describes the trade predictions from changes in import tariffs and preferences between both models. When country  $j$ 's import tariff on country  $i$  ( $\tau_{ij}$ ) increases, an exogenous transport cost model will predict only changes in  $j$ 's imports from  $i$ . The price of  $j$ 's imports from  $i$  will become more expensive (equation (3)) while its import quantity and value from  $i$  will fall (equation (4)).

When transport cost is endogenized with the round trip effect, however,  $j$ 's import tariff increase will affect both  $j$ 's imports from and exports to  $i$ . This is due to the endogenous response from  $j$ 's imports and export freight rates to  $i$ . First, country  $j$ 's import freight rate will fall to mitigate the impact of the tariff (equation (9)). This decrease is not enough to offset  $j$ 's net import price increase from  $i$  (equation (10)) which results in a fall in  $j$ 's import quantity and value (equation (11)). This import fall,

<sup>10</sup>If countries are symmetric, the preference parameters would be the same:  $a_{ij} = a_{ji}$ . The freight rates each way will be half the marginal cost:  $T_{ij}^{Sym} = T_{ji}^{Sym} = \frac{1}{2} c_{ij}^{\leftrightarrow}$ . See theory appendix A.2 for more details.

<sup>11</sup>If countries are symmetric, they face the same prices, quantities, and values. See theory appendix A.2.

however, is less than the import fall in the exogenous model.

Second, the impact of  $j$ 's import tariff on  $i$  also spills over to  $j$ 's exports to  $i$  due to the round trip effect. The fall in imports from  $i$  to  $j$  decreases transport services on route  $ij$  which translates into a decrease in transport services in the opposite direction from  $j$  to  $i$ . All else equal, the corresponding fall in transport quantity from  $j$  to  $i$  due to the round trip effect results in an increase in  $j$ 's export freight rate to  $i$ . Country  $j$ 's export price to  $i$  increases from the rise in export freight rate while its export quantity and value to  $i$  decreases. The following lemma can be shown:<sup>12</sup>

**Lemma 1.** *When transport costs are assumed to be exogenous, an increase in the origin country  $j$ 's import tariffs on its trading partner  $i$ 's goods only affects its imports from its partner. Its import price from its partner will rise while its import quantity and value will fall.*

$$\frac{\partial p_{ij}^{Exo}}{\partial \tau_{ij}} > 0, \frac{\partial q_{ij}^{Exo}}{\partial \tau_{ij}} < 0 \text{ and } \frac{\partial X_{ij}^{Exo}}{\partial \tau_{ij}} < 0$$

*When transport cost is endogenous and determined on a round trip basis, this import tariff increase will affect both the origin country's imports and exports to its partner. On the import side, the origin country's import freight rate falls in addition to the effects under the exogenous model. The import quantity and value decrease is larger under the exogenous model.*

$$\frac{\partial T_{ij}^R}{\partial \tau_{ij}} < 0, \frac{\partial p_{ij}^R}{\partial \tau_{ij}} > 0, \frac{\partial q_{ij}^R}{\partial \tau_{ij}} < 0, \frac{\partial X_{ij}^R}{\partial \tau_{ij}} < 0, \frac{\partial q_{ij}^{Exo} / \partial \tau_{ij}}{\partial q_{ij}^R / \partial \tau_{ij}} > 0 \text{ and } \frac{\partial X_{ij}^{Exo} / \partial \tau_{ij}}{\partial X_{ij}^R / \partial \tau_{ij}} > 0$$

*On the export side, the exogenous trade model does not predict any changes. However, the endogenous model predicts a fall in the origin country's export freight rate and price to its partner while its export quantity and value increases.*

$$\frac{\partial T_{ji}^R}{\partial \tau_{ij}} > 0, \frac{\partial p_{ji}^R}{\partial \tau_{ij}} > 0, \frac{\partial q_{ji}^R}{\partial \tau_{ij}} < 0 \text{ and } \frac{\partial X_{ji}^R}{\partial \tau_{ij}} < 0$$

Assuming linear demand, Ishikawa and Tarui (2016) find a similar spillover result as I do in their theoretical study on the impact of domestic trade restrictions on domestic exports in the presence of the round trip effect. Focusing intermediate goods, Mostashari (2010) finds evidence broadly consistent with the bilateral export impact of a country's import tariff as I do with the round trip effect. Unilateral import tariff cuts by developing countries can contribute to their bilateral exports to the US since

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<sup>12</sup>See Theory Appendix for proof.

these tariff cuts reduce the cost of their imported intermediate goods which makes their exports, using these intermediate goods, relatively more competitive.

Next, I consider an increase in country  $j$ 's preference for country  $i$ 's good ( $a_{ij}$ ). The exogenous transport cost model makes the same predictions where only  $j$ 's imports from  $i$  increases, with the exception that import prices stay the same (equation (3)). In the endogenous model with the round trip effect, this preference change will impact both imports and exports like in the tariff case. The only difference here is that an increase in preferences would increase  $j$ 's import prices from  $i$  (equation (10)). This import increase is less than the import increase in the exogenous model. The following lemma can be shown:<sup>13</sup>

**Lemma 2.** *When transport costs are assumed to be exogenous, an increase in origin country  $j$ 's preference for its trading partner  $i$ 's goods only affects its imports from its partner. Its import quantity and value from  $i$  will increase while leaving its import price from  $i$  unchanged.*

$$\frac{\partial p_{ij}^{Exo}}{\partial a_{ij}} = 0, \quad \frac{\partial q_{ij}^{Exo}}{\partial a_{ij}} > 0 \text{ and } \frac{\partial X_{ij}^{Exo}}{\partial a_{ij}} > 0$$

*When transport cost is endogenous and determined on a round trip basis, this preference increase will affect both the origin country's imports and exports to its partner. On the import side, the home country's import transport cost and price from its partner rises on top of the import changes predicted by the exogenous model. The import quantity and value increase is larger under the exogenous model.*

$$\frac{\partial T_{ij}^R}{\partial a_{ij}} > 0, \quad \frac{\partial p_{ij}^R}{\partial a_{ij}} > 0, \quad \frac{\partial q_{ij}^R}{\partial a_{ij}} > 0, \quad \frac{\partial X_{ij}^R}{\partial a_{ij}} > 0, \quad \frac{\partial q_{ij}^{Exo}/\partial a_{ij}}{\partial q_{ij}^R/\partial a_{ij}} > 0 \text{ and } \frac{\partial X_{ij}^{Exo}/\partial a_{ij}}{\partial X_{ij}^R/\partial a_{ij}} > 0$$

*On the export side, the home country's export transport cost and export price to its partner falls while its export quantity and value increases.*

$$\frac{\partial T_{ji}^R}{\partial a_{ij}} < 0, \quad \frac{\partial p_{ji}^R}{\partial a_{ij}} < 0, \quad \frac{\partial q_{ji}^R}{\partial a_{ij}} > 0 \text{ and } \frac{\partial X_{ji}^R}{\partial a_{ij}} > 0$$

There are two main differences between these models. The first is that the transport costs in the round trip model mitigates the effects of underlying changes in trade demand and supply like tariffs and preferences. This first point can be generated in a transport model with rising costs. However, since the transport industry here is assumed to be perfectly competitive with constant costs, this prediction is solely generated by

<sup>13</sup>See Theory Appendix for proof.

the round trip effect.

The second difference is that any demand or supply trade changes for a country will have spillover effects on its opposite direction trade with the same partner. This prediction, using a partial equilibrium Armington trade model, is a novel result due to the round trip effect. In the case of Lemma 1, an import tariff will therefore also translate into an export tax. The following proposition can be stated:

**Proposition 1.** *The round trip effect mitigates trade shocks on the origin country's imports from its trading partner via its import transport cost and generates spillovers of this shock onto the origin country's exports to the same partner. The same applies for trade shocks on the origin country's exports to its trading partner. A model with exogenous transport costs will not predict both these effects. An increase in the origin country's tariffs on its trading partner decreases both its imports from and exports to the same partner. The same applies inversely for a positive preference shock.*

Lerner (1936) symmetry predicts that a country's unilateral tariff increase on one partner will act as an export tax and reduce its exports to all its partners. My trade and transportation model predicts a distinct and more specific channel which impacts the country's exports to the same partner. Lerner symmetry would not predict this bilateral effect. Moreover, the Lerner symmetry prediction relies on the balanced trade condition within a general equilibrium setting. My model is partial equilibrium and does not require this condition.

### 3 Data

This section introduces a novel high frequency data set on port-level container freight rates which is then matched with data on trade in containers. This data provides suggestive empirical evidence for my theoretical predictions based on the round trip effect.

#### 3.1 Container freight rates and containerized trade

Drewry Maritime Research (Drewry) compiles port-level container freight rate data from importer and exporter firms located globally.<sup>14</sup> To my knowledge, this data set is the only source of container freight rates on all major global routes.<sup>15</sup> The ports in this

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<sup>14</sup>Many thanks to Nidhin Raj, Stijn Rubens, and Robert Zamora at Drewry for their help.

<sup>15</sup>Worldfreightrates.com also publishes port-level freight rates. However, Marcelo Zinn who owns this website explained that some of his freight rates are generated from a proprietary algorithm. I was

data set are the biggest globally and handle more than one million containers per year. These monthly or bimonthly spot market rates are for a standard 20-foot container.

In addition to spot market rates, long-term contracts are also used in the container market. My spot rates choice is driven by data availability. Contract rates are confidentially filed with the Federal Maritime Commission (FMC) and my Freedom of Information Act requests have been denied.<sup>16</sup> That being said, spot prices play an important role in informing long-term contracts and can shed light on the container transport market. Shorter-term contracts are increasingly favored due to over-capacity in the market (conversations with Director of FMC Office of Economics & Competition Analysis, Roy Pearson). Longer term contracts are also increasingly indexed to spot market rates due to price fluctuations ([Journal of Commerce, January 2014](#)). Furthermore, most firms split their cargo between long-term contracts and the spot market to smooth volatility (conversations with Roy Pearson). Freight forwarding companies like UPS or FedEx offer hybrid models that allow their customers to switch to spot rate pricing when these rates fall below agreed-upon contract rates ([Journal of Commerce, June 2016](#)).

While containers carry the two-thirds of world trade by value (World Shipping Council), they do not carry all types of products. Cars and oil, for example, are not transported via containers. As such, in order to compare apples to apples, I focus my analysis on trade in containers. Since containerized trade data is not readily available for all other countries apart from the United States, my analysis is limited to US trade in this paper. Drewry collects freight-rate data on the three of the largest US container ports (Los Angeles and Long Beach, New York, and Houston) that handle 16.7 million containers annually combined—more than half of the annual US container volume (MARAD). There are 68 port pairs which include these three US ports.

Monthly containerized US trade data at the port level is available from USA Trade Online at the six-digit Harmonized System (HS) product code level. It includes the trade value and weight between US ports and its foreign partner countries.<sup>17</sup> My level of observation is at the US port, foreign partner country, and product level, but for ease of exposition I will refer to both destination and origin locations as a country. Both

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not able to ascertain the proportion of real versus generated data from Mr. Zinn. Drewry's data reflects the actual prices paid.

<sup>16</sup>For more details, refer to the Data Appendix.

<sup>17</sup>Since my freight rates data is at the port-to-port level, I have to aggregate my data to the US port and foreign country level. See Data Appendix for further details.



freight rates and trade value data are converted into real terms. Containerized trade account for 62% of all US vessel trade value in 2015.<sup>18</sup> My matched freight rates and trade data set represents at least half of total US containerized trade value in 2014 (USA Trade Online).<sup>19</sup> The time period of this matched data set is from January 2011 to June 2016.

### 3.2 Summary Statistics

Table 1 shows the summary statistics for US freight rates, as well as containerized trade value, weight, and value per weight. As a first pass, this data set is broken down by US exports, US imports, and total US trade. These variables are on average higher on for US imports than exports. While the higher import values and weight are not surprising since US is a net-importer, freight rates are also higher for US imports than exports. The value per weight of US imports, a crude measure of quality, is on average higher than US exports. These patterns are also affirmed using more aggregate data on container volumes (table A.1). After converting per unit freight rates into ad valorem equivalents, US iceberg cost are also higher for imports (table A.1). However, iceberg costs belie two endogenous components: freight rates and trade value. Container freight rates and containerized trade value are jointly determined since they are market outcomes. This paper will study them as such.

The summary statistics in table 1 affirms the “shipping the good apples out” phenomenon first introduced by Alchian and Allen (1964) and extended by Hummels and Skiba (2004)—the presence of per unit transportation costs lowers the relative price of higher-quality goods. Table 1 shows the presence of higher US import freight rates as well as higher import value per weight relative to exports. Similarly, table A.1 shows that the value per container for imports are higher than exports as well.

### 3.3 Suggestive Evidence

My novel data set on container freight rates, matched with containerized trade data, is uniquely positioned to provide suggestive evidence for my theoretical predictions from the previous section. The first suggestive evidence is as follows:

**Suggestive Evidence 1.** *A positive deviation from the average freight rates from  $i$  to  $j$*

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<sup>18</sup>Shipping vessels that carry trade without containers include oil tankers, bulk carriers, and car carriers. Bulk carriers transport grains, coal, ore, and cement.

<sup>19</sup>This is a conservative estimate, particularly for Europe, since Drewry does not collect data on adjacent ports even though they are in different countries. See the Data Appendix for more details.

Table 1: Summary statistics: Monthly container freight rates and containerized trade

	US Exports	US Imports	Full Sample
Freight Rate (\$)	1399 (689)	2285 (758)	1842 (849)
Value (\$ bn)	.117 (.21)	.422 (1.8)	.27 (1.3)
Weight (kg bn)	.0521 (.13)	.0811 (.33)	.0666 (.25)
Value per Wt.	4.01 (2.6)	4.27 (4.5)	4.14 (3.6)
Observations	2842	2842	5684

Standard deviation in parentheses. Since this panel is balanced, the average ocean distance for both US exports and imports is the same at 8061 n.m.

Sources: Drewry, Census Bureau, sea-distances.org (Monthly 2011-June 2016).

*is correlated with a negative deviation from the average opposite direction freight rates from  $j$  to  $i$ .*

From equation (6) in the theory section, the optimal freight rates between a port pair add up to the marginal cost of a round trip. This means that, conditional on the round trip marginal cost, freight rates between port pairs are negatively correlated. Figure 3 confirms this inverse relationship.<sup>20</sup> A one percent deviation from the average container freight rates from  $i$  to  $j$  is correlated across time with a negative deviation of 0.8 percent from the average container freight rates from  $j$  to  $i$ .

This inverse relationship is not typically predicted in the trade literature. If freight rates can be approximated by distance and therefore is symmetric, as assumed in some of the literature, one would expect the correlation in figure 3 to be zero. If freight rates were exogenous, one might expect no correlation or a noisy estimate. In fact, as noted in the introduction, when Samuelson (1954) introduced the iceberg transport cost he provided two caveats. First, if transport costs varied with trade volume, then transport costs would not be constants. Second, since realistically there are joint costs of a round trip for transportation, the going and return transport costs will tend to move in opposite

<sup>20</sup>Route fixed effects, which are directional port-pair fixed effects, are included in the regression used to construct this figure. As such, this figure is identified from the time variation within routes. If the fixed effects were at the dyad, non-directional level, then a mechanical negative correlation could arise. However, this is not the case here. See table A.2 for further details.

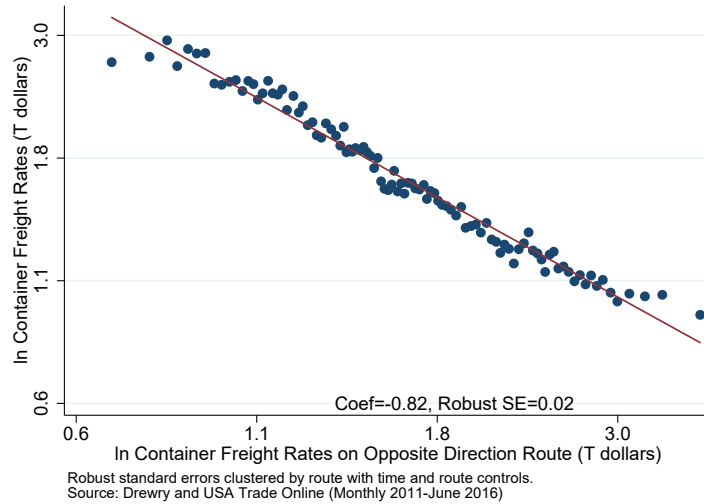


Figure 3: Correlation between container freight rates within port pairs

$$\ln T_{ijt} = \beta_0 + \beta_1 \ln T_{jit} + d_{ij} + \gamma_t + \varepsilon_{ijt}$$

directions depending on the demand levels.<sup>21</sup> I confirm his caveats here.

Furthermore, the presence of this inverse relationship means that container routes can generally be represented by the port-pairs in my data. One contributing reason for this is the significant increase in average container ship sizes—container-carrying capacity has increased by about 1200% since 1970 (Container ship design, [World Shipping Council](#)). The increase in average ship size has resulted in downward pressure on the average number of port calls per route because larger ships face greater number of hours lost at port. Ducruet and Notteboom (2012) shows that the number of European port calls per loop on the Far East-North Europe trade has decreased from 4.9 ports of call in 1989 down to 3.35 in December 2009. Second, this size increase has also generated a proliferation of hub-and-spoke networks which also decreases the number of port calls per route: 85 percent of container shipping networks are of the hub-and-spoke form (Rodrigue, Comtois and Slack (2013)) and 81 percent of country pairs are connected by one transshipment port or less (Fugazza and Hoffmann (2016)).

The round trip effect can be also shown using container quantities directly. Figure [A.1](#) highlights a positive relationship between container volume gap and freight rate gap between countries. As the number of containers going back and forth between

<sup>21</sup>Systematic current and wind conditions can contribute to this inverse relationship. Chang et al. (2013) estimates a modest range of 1 to 8 percent in time savings when ships utilize strong currents or avoid unfavorable currents in the North Pacific. As such, the highly negative and significant relationship in figure 3 is not solely driven by currents.

countries increases, the freight rate gap between these countries increases as well.

This second suggestive evidence shows that a country’s imports and exports with a particular partner are linked via its outgoing and return transport costs with that partner:

**Suggestive Evidence 2.** *A positive deviation from the average containerized trade value from  $i$  to  $j$  is correlated with a positive deviation from the average opposite direction freight rates from  $j$  to  $i$ . The same applies for containerized trade weight while the opposite applies for value per weight.*

This linkage has two components. First, intuitively, containerized trade value and weight from  $j$  to  $i$  decreases with freight rates on the same route (Panel A, table 2). Second, freight rates are negatively correlated within a route as established in the first suggestive evidence. As such, containerized trade value and weight on the outgoing direction from  $j$  to  $i$  increases with opposite direction freight rates ( $i$  back to  $j$ , Panel B table 2). The opposite relationship applies for value per weight. This is because the first component of the linkage is positive—value per weight increases with freight rates—which confirms the Alchian-Allen effect (column (3,) Panel B table 2).

Table 2: Regression of containerized trade on freight rates

	(1)	(2)	(3)
	ln Value	ln Weight	ln Value/Wgt
<b>Panel A: Regression of trade on freight rates</b>			
ln Freight Rate	-0.701** (0.241)	-1.086*** (0.207)	0.385*** (0.0729)
Observations	5684	5684	5684
F	8.449	27.46	27.95
<b>Panel B: Regression of trade on opposite direction freight rates</b>			
ln Opposite Direction FR	0.723** (0.238)	1.076*** (0.204)	-0.353*** (0.0736)
Observations	5658	5658	5658
F	9.196	27.85	23.03
<b>Panel C: Regression of Panel B without China</b>			
ln Opposite Direction FR	1.028*** (0.233)	1.283*** (0.208)	-0.255*** (0.0740)
Observations	5268	5268	5268
F	19.54	38.03	11.86

Robust standard errors clustered by route in parentheses. \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$   
Time and dyad level fixed effects were included.

Source: Drewry and USA Trade Online (Monthly 2011-June 2016)

Specifically, within a port-pair dyad, a one percent deviation from the average opposite direction freight rates (from  $i$  to  $j$ ) is correlated across time with a 0.7 percent increase in average aggregate containerized trade value in the going direction from  $j$  to  $i$  (column (1), Panel B table 2 and figure 4). In column (2), a within dyad one percent increase from the average opposite direction freight rates is correlated across time with a 1.1 percent increase in average aggregate containerized trade weight in the going direction. Correspondingly in column (3), the value per weight on the outgoing direction *decreases* with opposite direction freight rates. A within dyad one percent increase in the average opposite direction freight rates (from  $j$  to  $i$ ) is correlated across time with a 0.4 percent decrease in average aggregate containerized trade quality (from  $i$  to  $j$ ).

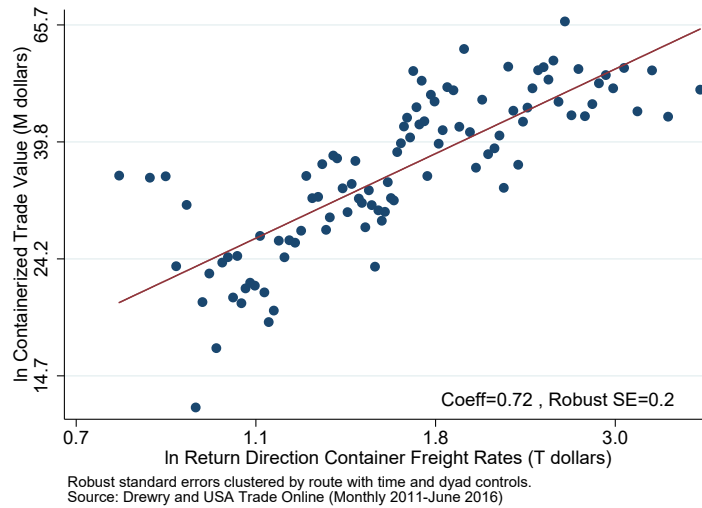


Figure 4: Correlation between containerized trade value and opposite direction freight rates

$$\ln X_{ijt} = \beta_0 + \beta_1 \ln T_{jit} + d_{ij}^{\leftrightarrow} + \gamma_t + \varepsilon_{ijt}$$

These findings suggest the presence of the round trip effect. Absent this effect, there should be no systematic relationship between containerized trade on the outgoing direction and freight rates on the incoming direction. The same applies for trade on the incoming direction and freight rates on the outgoing direction. While it is acknowledged here that the dominance of processing trade can also contribute to this relationship, these results are robust to removing the main country that conducts processing trade with the US–China (Panel C table 2).<sup>22</sup>

<sup>22</sup>The processing trade share of China exports to US by value is more than 50 percent in 2004 (Hammer (2006)). In the example of US and China processing trade, US exports inputs to China which assembles them into final goods for re-export to the US. A decrease in the transport cost from US to

## 4 Empirical Approach

This section presents my strategy for estimating the elasticity of containerized trade with respect to container freight rates. I introduce my estimating equation, explain the endogeneity issue from an ordinary least squares (OLS) estimation, and detail an instrumental variable (IV) using the round trip effect insight to address the potential bias. I then discuss the validity of my identification approach.

### 4.1 Identification of the impact of freight rates on trade

The relationship between container freight rates and containerized trade for product  $n$  on route  $ij$  at time  $t$  estimated below is loosely based on the canonical trade flow determinants in gravity equations (Head and Mayer (2014)):

$$\ln X_{ijnt} = \alpha \ln T_{ijt} + S_{it} + M_{jt} + d_{ijn}^{\leftrightarrow} + \varepsilon_{ijnt} \quad (12)$$

where  $X_{ijnt}$  is the containerized trade on route  $ij$  of product  $n$  at time  $t$  and  $T_{ijt}$  is the container freight rate on route  $ij$  at time  $t$ .<sup>23</sup> I control for the time varying export propensity of exporter country  $i$  such as production costs with an exporter-by-time fixed effect ( $S_{it}$ ) and for the time-varying importer country  $j$ 's determinants of import propensity with an importer-by-time fixed effect ( $M_{jt}$ ). These fixed effects also control for time-varying shocks to these countries.

The dyad-by-product level fixed effect,  $d_{ijn}^{\leftrightarrow}$ , accounts for time-invariant product-level comparative advantage differences across country pairs in addition to time-invariant bilateral characteristics like distance, shared borders and languages.<sup>24</sup>  $d_{ijn}^{\leftrightarrow}$  can also control for the constant tariff rate differences across countries that can contribute to differences in trade levels since the variation in tariff rates during this sample period is small—an average annual percentage point change of 0.2 with almost 80 percent of the changes being below 0.25 percentage points (figure A.4). The error term is  $\varepsilon_{ijnt}$ . To address potential auto-correlation in my panel data set, I report standard errors adjusted for clustering within routes. In my results, I include a specification with separate controls for dyad ( $d_{ij}^{\leftrightarrow}$ ) and product ( $\gamma_n$ ) fixed effects.

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China will decrease the input cost which can potentially translate into larger re-export value or weight back to the US.

<sup>23</sup>Containers are generally considered a commodity which do not vary by product hence freight rates are not product-specific. This is particularly true for my container spot market rates data.

<sup>24</sup>Similar specifications at the country level have been done by Baier and Bergstrand (2007) to estimate the effects of free trade agreements on trade flows and Shapiro (2015) to estimate the trade elasticity with respect to ad-valorem trade cost.

My specification exploits the panel nature of my data set and observed per unit freight rates in order to identify the containerized trade elasticity with respect to freight rates. To my knowledge, this is the first paper to use transportation-mode specific panel data and its corresponding observed transport cost to identify a mode-specific trade elasticity with respect to transport cost. The only other paper closest to my methodology is Shapiro (2015) who uses ad-valorem shipping cost across multiple modes. The key difference between my estimating equation and typical gravity models is that gravity models are estimated using ad-valorem trade costs while my container freight rates data is at the per-unit level. As such, I am estimating the elasticity of containerized trade with respect to per unit freight rates and not a general trade elasticity with respect to trade cost.

The elasticity of containerized trade with respect to freight rates,  $\alpha$ , is the parameter of interest here. As mentioned earlier, the main challenge for this exercise is that container freight rates and trade are jointly determined. As such, an OLS estimation of  $\alpha$  in (12) will suffer from simultaneity bias. Furthermore, this bias will be downward due to two factors. The first is due to the simple endogeneity of transport costs. An unobserved positive trade shock in  $\varepsilon_{ijmt}$  will simultaneously increase freight rates  $T_{ijt}$  and containerized trade  $X_{ijmt}$ . This results in a positive correlation between  $T_{ijt}$  and  $X_{ijmt}$  which masks the negative impact of freight rates on trade. The second factor is due to the round trip effect. Between a dyad, routes with higher demand, and thus higher container volume and trade value, will face relatively higher freight rates compared to routes with lower demand. This further contributes to the positive correlation between  $T_{ijt}$  and  $X_{ijmt}$ .<sup>25</sup> In order to consistently estimate  $\alpha$ , I require a transport supply shifter that is independent of transport demand.

My proposed transport supply shifter to identify product-level containerized trade demand for route  $ij$  is its opposite direction aggregate containerized trade shocks (on route  $ji$ ). Aggregate trade shocks on opposite direction route  $ji$  will affect the aggregate supply of containers on route  $ji$  and the original direction route ( $ij$ ) due to the round trip effect. The latter provides an aggregate transport supply shifter to identify the product-level containerized trade demand for route  $ij$ . Figure A.2 illustrates this.<sup>26</sup>

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<sup>25</sup>It is therefore important to highlight that the demand for containers, being a demand that is derived from the underlying demand for trade that is transported in containers, moves closely with the demand for trade that is transported in containers. I confirm this positive and significant correlation with data on container volumes from the United States Maritime Administration (figure A.3).

<sup>26</sup>This more information on this figure, see appendix section A.1 which presents a graphical illustra-

A positive trade shock for route  $ji$  in the top graph increases its corresponding transport demand. As transport supply on route  $ji$  responds, the round trip effect implies that the aggregate transport supply in the original direction (route  $ij$ ) will also increase. This latter aggregate increase in transport supply can identify the containerized trade demand for route  $ij$  conditional on demand shifts between the routes being uncorrelated. The basic idea here, then, is to utilize the round trip insight and instrument for  $T_{ijt}$  in equation (12) with its opposite direction trade  $X_{jit}$ .

This approach is problematic, however, if demand shocks between countries  $i$  and  $j$  are not independent. Examples of this violation include exchange rate fluctuations, processing trade, and the signing of any free trade agreements between countries. As such, I construct a Bartik-type instrument in the section below that predicts the opposite direction trade on route  $ji$  but is independent of the unobserved demand determinants on route  $ij$ .

## 4.2 Instrumental Variable

To introduce my instrument, I start by showing a series of transformations on country  $j$ 's total exports to  $i$  across all products at time  $t$  ( $X_{jit}$ ):

$$X_{jit} = \sum_N X_{jint} \quad (13)$$

The sum of  $j$ 's exports to  $i$  at time  $t$  is the sum of all products  $n$  that  $j$  exports to  $i$  at time  $t$  ( $X_{jint}$ ). Multiplying and dividing by country  $j$ 's total exports of product  $n$  to all of its partners in instrument group  $A$  ( $X_{jAnt}$ ) yields the following:

$$X_{jit} = \sum_N X_{jint} = \sum_N X_{jAnt} \times \frac{X_{jint}}{X_{jAnt}} \equiv \sum_N X_{jAnt} \times \omega_{jint} \quad (14)$$

where the first term is  $j$ 's exports of  $n$  to its trading partners in set  $A$  and the second term  $\omega_{jint} \equiv \frac{X_{jint}}{X_{jAnt}}$  is  $j$ 's export share of product  $n$  to  $i$ . Both these terms are summed across all products  $n$ .

My predicted trade measure for  $j$ 's exports to  $i$ , in the spirit of Bartik (1991), is the lagged-weighted sum of country  $j$ 's exports to all its partners except for  $i$ . The weights are the product shares of products that  $j$  exported to  $i$  in January 2003, the earliest month available in my data set, and the sum is country  $j$ 's exports to all of its partners except for country  $j$  at present time:

$$Z_{jit} \equiv \sum_N X_{j,A \setminus i, nt} \times \frac{X_{jint}^b}{X_{jAnt}^b} \equiv \sum_N X_{j,A \setminus i, nt} \times \omega_{jint}^b \quad (15)$$

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tion of the round trip effect using a simple linear transport demand and supply model.



where the first term is the sum of  $j$ 's exports of product  $n$  to all its partners except for  $i$  at present time  $t$  ( $X_{j,A \setminus i,nt} = \sum_A X_{jAnt} - X_{jint}$ ). The second term is  $j$ 's lagged product-level export shares to  $i$ , at least eight years prior in January 2003 (time  $t^b$ ). Instrument  $Z_{jit}$  is obtained by summing both these terms across all products.

This instrument  $Z_{jit}$  (equation (15)) differs from the expression in (14) in two respects. First, in place of the present-time product trade shares—the first term in (14), I use the earliest shares available in my data set from at least eight years prior—January 2003. This modification is intended to mitigate the simultaneity bias from using contemporaneous import shares. Second, I remove country  $i$  from country  $j$ 's total exports of product  $n$  to all of its trading partners. This is in order to avoid a mechanical correlation between the instrument and  $j$ 's direct exports to  $i$ .<sup>27</sup>

### 4.3 Validity of identification approach

My IV strategy uses the predicted trade on a route ( $Z_{jit}$ ) to identify its opposite direction product level trade demand ( $X_{ijnt}$ ). Trade on route  $ji$  ( $X_{jit}$ ) is correlated with its return direction freight rates ( $T_{jit}$ ) due to the round trip effect as established earlier. Since  $Z_{jit}$  predicts  $X_{jit}$ , the predicted trade measure  $Z_{jit}$  should be correlated with the return direction freight rates  $T_{jit}$  as well.

In order for my IV strategy to be valid, the predicted trade on a route ( $Z_{jit}$ ) has to be generally uncorrelated with unobserved changes in product-level demand on the return direction route ( $\text{corr}(Z_{jit}, \varepsilon_{ijnt}) = 0$ ). Since the construction of  $Z_{jit}$  excludes present-time  $j$  exports to country  $i$ , it is not a function of bilaterally correlated present-time demand shocks between  $i$  and  $j$ . Since  $Z_{jit}$  excludes  $X_{jint}$  for all products, any shocks that affect  $j$ 's demand for  $i$  ( $\varepsilon_{ijnt}$ ) that will also affect  $i$ 's demand for  $j$  is no longer part of  $Z_{jit}$ . These shocks include the examples raised earlier: exchange rate fluctuations, processing trade, and the signing of any free trade agreements between countries.

I address potential violations with fixed effects that control for national monthly variation in container demand by importer, exporter, and fixed differences across dyad and products. These national and dyad level controls are at the foreign country and US port level so these fixed effects will also absorb any US port-level variation that is correlated with trade determinants. Therefore, my identification assumption here is

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<sup>27</sup>My instrument centers around the US due to the availability of US containerized trade data. For clarity of exposition above I have assumed that the US is country  $j$  and used country  $j$ 's exports in my explanation above. However, if the US is country  $i$  in the example above I will use US imports from all its partners to construct my instrument.

that the deviation in the predicted trade measure for route  $ij$  from importer and exporter trends at the foreign country and US port level, as well as the fixed comparative advantage between  $i$  and  $j$ , is uncorrelated with the deviation in unobserved product-level demand changes.

One potential threat to my identification is correlated product-level demand shocks across countries like in the case of supply chains. Take the example of China, which exports steel to the US and the UK. The UK, in turn, processes the steel into a finished product, like steel cloth or saw blades to export to the US. My instrument to identify US demand for steel products from the UK (route  $UK - US$ ) is the opposite direction predicted trade to the UK  $US - UK$  ( $Z_{US-UK}$ ), which is the sum of US weighted exports to all its trading partners except the UK (equation (15)). This means that  $Z_{US-UK}$  includes US exports to China. Now say that China experiences a supply shock, like an increase in steel manufacturing wages, which raises the input price of their steel production. There will be two effects from steel becoming more expensive. The first is that US demand for Chinese steel will fall. The second effect is US demand for UK steel products that use Chinese steel as inputs will also fall. Through the round trip effect, US exports to China on route  $US - C$  will also fall which is included in my instrument  $Z_{US-UK}$ . This means that my instrument is correlated with the original steel supply shock in China which affects the unobserved US demand for steel products from the UK.

In order to make sure that supply chains are not driving my results, I restrict my instrument group (set  $A$  in equation (15)) to high-income OECD countries following the intuition of Autor, Dorn and Hanson (2013) as well as Autor et al. (2014). Since supply chains can occur between high-income countries as well, as a robustness check I remove products whose production process is typically fragmented in the following section. I find that my estimates retain the same sign and are within a confidence interval of my baseline results.

While it is not possible to test the validity of my exclusion restriction, I can show the absence of correlation between my predicted trade measure and an approximation of  $\varepsilon_{jmt}$ —manufacturing wages. Since most manufactured products are transported via containers (Korinek (2008)) and wages are inputs to production, manufacturing wages are correlated with unobserved product-level demand determinants. Figure 5 shows this absence of correlation with a visualized regression of my predicted trade measure and manufacturing wages. Specifically, country  $j$ 's predicted exports to  $i$  on route

$j_i$  is uncorrelated with country  $i$ 's manufacturing wages which can approximate  $i$ 's unobserved product-level demand determinants for  $j$ . While this exercise is insufficient to definitely show that my instrument is valid, it plays the same role as a balancing test in showing the absence of evidence for the exclusion restriction violation.

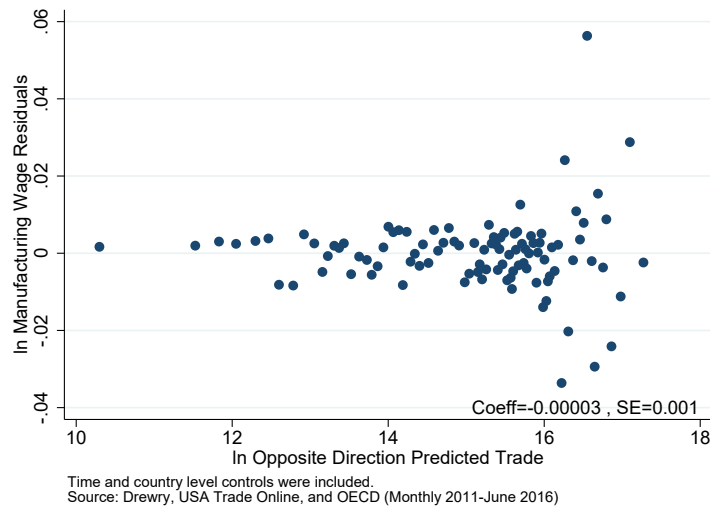


Figure 5: Balancing Test: Correlation between instrument and an approximation of demand determinants using manufacturing wages

To provide evidence that this Bartik-style predicted trade measure has sufficient power to identify the desired effects, I present my first stage results in figure A.5. Controlling for constant bilateral differences across routes, as well as time-varying importer and exporter characteristics, a 10 percent increase in my predicted trade measure corresponds to a significant and positive 0.6 percent increase in the opposite direction container freight rate.

## 5 Impact of Freight Rates on Trade

This section presents the results from my OLS estimates as well as two-stage least squares IV regressions. Trade outcomes are aggregated to the HS2 product level and measured in value, weight, and value per weight. I first present my estimates with only OECD countries due to my instrument group restriction to OECD countries in order to address supply chain concerns. I also compare my estimates to the literature. Next, I discuss my results when expanding my second stage to include all countries in my sample size. Lastly, I discuss various robustness checks.

## 5.1 Main Results

Panel A in in table 3 presents the containerized trade value estimates. Column (1) presents the OLS estimates with separate controls for importer-by-time, exporter-by-time, dyad, and products. A one percent increase in container freight rates is correlated with a significant 0.7 percent decrease in trade value. This estimate is robust to controlling for comparative advantage with dyad-by-product fixed effects—a one percent increase in container freight rates corresponds to a significant 0.5 percent decrease in trade value (column (2)). After addressing the potential simultaneity bias with my predicted return direction trade instrument, the IV estimates are, as expected, more pronounced in magnitude. Column (3) shows that a one percent increase in per unit container freight rates decreases containerized trade value by 3.7 percent with separate product and dyad controls. This result is robust to including dyad-by-product controls (column (4))—a one percent increase in freight rates decreases trade value by 2.8 percent. The IV approach here yields trade elasticity estimates that are roughly five times more sensitive than the OLS estimates.

Panel B in table 3 presents the results using containerized trade weight as the outcome. The weight estimates are overall larger than the value estimates. This is a reflection of trade weight being a closer proxy to quantity while value contains both quantity and price. Prices tend to increase with freight rates while the opposite is true for quantity. The OLS estimates in column (1) show that a one percent increase in freight rates correspond to a one percent decrease in trade weight. With the inclusion of dyad-by-product controls, the estimate decreases slightly—a one percent increase in freight rates decrease trade weight by 0.8 percent (column (2)). In my IV estimates, a one percent increase in container freight rates decreases containerized weight by 4.8 percent (column (3)). With dyad-by-product controls, this estimate decreases slightly—a one percent increase in container freight rates decreases trade weight by 3.6 percent (column (4)). While the IV estimates here are not directly comparable to the literature, my OLS containerized trade weight estimates are comparable to the volume elasticities for air, truck, and rail (De Palma et al. (2011); Oum, Waters and Yong (1992)).<sup>28</sup>

Panel C in table 3 presents the containerized value per weight elasticity with respect to freight rates results. Containerized value per weight can be calculated using both the value and weight variables. This unit value calculation provides a crude mea-

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<sup>28</sup>Their aggregate volume elasticity with respect to transport cost is between -0.8 to -1.6 for air, -0.7 to -1.1 for truck, and -0.4 to -1.2 for rail.

Table 3: Containerized Trade Demand Estimates for OECD Countries

	(1)	(2)	(3)	(4)
	OLS	OLS	IV	IV
<b>Panel A: In Trade Value</b>				
In Freight Rate	-0.676*** (0.148)	-0.520*** (0.133)	-3.651*** (0.949)	-2.795** (0.903)
<b>Panel B: In Trade Weight</b>				
In Freight Rate	-1.061*** (0.196)	-0.837*** (0.177)	-4.790*** (1.126)	-3.631*** (0.969)
<b>Panel C: In Trade Value per Weight</b>				
In Freight Rate	0.384*** (0.0695)	0.317*** (0.0681)	1.138*** (0.224)	0.836*** (0.226)
Ex-Time & Im-Time FE	Y	Y	Y	Y
Dyad FE	Y		Y	
Product FE	Y		Y	
Dyad-Product FE		Y		Y
Observations	116887	116887	116887	116887
First Stage F			12.38	10.70

Robust standard errors in parentheses are clustered by route. \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

Results are robust to clustering at the route and product, dyad (two-way route), and dyad with products level. All variables are in logs. Trade value, weight, and value per weight are aggregated to the HS2 level. Table A.3 presents the first stage regressions. The predicted trade instrument is constructed at the HS4 level with Jan 2003 data using only OECD countries. Second stage is run on OECD countries as well.

Fixed Effects explanation: Ex-Time FE is exporter country and time fixed effects; Im-Time FE is importer country and time fixed effects.

Sources: Drewry and USA Trade Online (Monthly 2011-June 2016)

sure of product quality since it is not possible to distinguish whether higher unit value means a higher quality product within the same classification category or across product categories. The OLS estimate in column (1) shows that a one percent increase in container freight rates increases the product quality in containers by about 0.4 percent. When controlling for dyad-by-products, a one percent increase in freight rates increases product quality by 0.3 percent (column (2)). In my IV estimates, a one percent increase in freight rates increases containerized quality by 1.1 percent. This estimate decreases slightly with dyad-by-product controls—a one percent increase in freight rates increases containerized quality by 0.8 percent. My value per weight IV estimates are comparable to Hummels and Skiba (2004) who finds a price elasticity with respect to freight cost between 0.8 to 1.41 using two different sets of instruments.

## 5.2 Robustness Checks

My results are robust to a number of alternative specifications including sample size expansion, removal of products typically constructed in supply chains, product and time period aggregations, different product classifications, as well as base year change. These results are also robust to alternative levels of clustering—at the route and product, dyad (two-way route), and dyad with products levels. Overall, the first stage results suggest that my instrument is strong with F-statistics above the standard threshold of 10 suggested by Staiger and Stock (1994).

My results are qualitatively similar if I expand my sample beyond OECD countries to include the full set of countries in my data set, although the instrument has less power here since it is constructed only with OECD countries. These estimates have the same signs and are within one standard error of my baseline estimates (table 4).

Table 4: Containerized Trade Demand Estimates for All Countries

	(1)	(2)	(3)	(4)
	OLS	OLS	IV	IV
<b>Panel A: In Trade Value</b>				
In Freight Rate	-0.532*** (0.0969)	-0.460*** (0.110)	-3.873** (1.232)	-2.884** (0.956)
<b>Panel B: In Trade Weight</b>				
In Freight Rate	-0.716*** (0.118)	-0.633*** (0.133)	-5.222** (1.613)	-4.072** (1.256)
<b>Panel C: In Trade Value per Weight</b>				
In Freight Rate	0.184*** (0.0365)	0.173*** (0.0377)	1.349** (0.427)	1.188** (0.382)
Ex-Time & Im-Time FE	Y	Y	Y	Y
Dyad FE	Y		Y	
Product FE	Y		Y	
Dyad-Product FE		Y		Y
Observations	261249	261249	261249	261249
First Stage F			8.433	7.750

Robust standard errors in parentheses are clustered by route. \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

Results are robust to clustering at the route and product, dyad (two-way route), and dyad with products level. All variables are in logs. Trade value, weight, and value per weight are aggregated to the HS2 level. Table A.4 presents the first stage regressions. The predicted trade instrument is constructed at the HS4 level with Jan 2003 data using only OECD countries. Second stage is run on all countries.

Fixed Effects explanation: Ex-Time FE is exporter country and time fixed effects; Im-Time FE is importer country and time fixed effects.

Sources: Drewry and USA Trade Online (Monthly 2011-June 2016)

As mentioned earlier, supply chains can occur between high-income OECD countries. As such, I make sure that my results are not sensitive to supply chains by remov-

ing products whose production process is typically fragmented. Fort (2016) constructs a data set on plant-level decisions to fragment production in the US at the four-digit NAICS industry level. I remove the products in industries with a majority of production fragmentation after matching the four-digit NAICS industry to HS product codes using the concordance system from the Census Bureau. I find that my estimates retain the same sign and are within the confidence interval of my baseline results (table 5). The removed products constitute about 13 percent of the total containerized value trade (\$229 billion) which contribute to the lower significance levels of my results and loss of instrument power.

Table 5: Containerized Trade Demand Estimates for All Countries without Products Typically Fragmented in the Production Process

	(1)	(2)	(3)	(4)
	OLS	OLS	IV	IV
<b>Panel A: In Trade Value</b>				
In Freight Rate	-0.533*** (0.0980)	-0.467*** (0.111)	-5.979* (2.695)	-4.346* (2.023)
<b>Panel B: In Trade Weight</b>				
In Freight Rate	-0.724*** (0.118)	-0.643*** (0.133)	-7.769* (3.452)	-5.978* (2.689)
<b>Panel C: In Trade Value per Weight</b>				
In Freight Rate	0.191*** (0.0358)	0.176*** (0.0375)	1.790* (0.808)	1.631* (0.766)
Ex-Time & Im-Time FE	Y	Y	Y	Y
Dyad FE	Y		Y	
Product FE	Y		Y	
Dyad-Product FE		Y		Y
Observations	258532	258532	258532	258532

Robust standard errors in parentheses are clustered by route. \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

Products that are typically fragmented in the production process (as identified in Fort (2016)) are removed from sample. All variables are in logs. Trade value, weight, and value per weight are aggregated to the HS2 level. Table A.6 presents the first stage regressions. The predicted trade instrument is constructed at the HS4 level with Jan 2003 data using only OECD countries.

Fixed Effects explanation: Ex-Time FE is exporter country and time fixed effects; Im-Time FE is importer country and time fixed effects.

Sources: Drewry and USA Trade Online (Monthly 2011-June 2016)

These results are robust to product aggregation as well (table A.5). The estimates have the same signs and are within one confidence interval of my baseline estimates. To ensure that the historical data—January 2003—used to construct the instrument is not driving my results, I construct the same instrument using January 2009 data and obtain qualitatively similar results (table A.7).

Since my data is at the monthly period, these elasticities should be higher than a more aggregated time period since they take into account the willingness of importers and exporters to substitute shipping their goods across time. Their ability to substitute is easier over a shorter time period compared to a longer period. I show that this is the case—aggregating the monthly estimation to the annual level reduces the elasticity by at least half or more (table A.9). Steinwender (Forthcoming) finds the same reduction in her elasticities when aggregating her daily data upwards.

Last but not least, I evaluate these estimates using the Rauch (1999) test which predicts that these elasticities should be more elastic for more homogeneous goods. Using the concorded product classifications from Rauch (1999), I divide my sample into homogeneous goods (grouping both homogeneous and reference-price goods from his classification) and differentiated goods. I show that the differentiated goods sample have much smaller elasticities in magnitude compared to more homogeneous goods across all three outcome variables (table A.11). Shapiro (2015) finds the same magnitude differences in his elasticities after dividing his sample into these product classifications.

## 6 Counterfactual

Utilizing the trade elasticities from my IV results along with the trade and transport model, I analyze a doubling of US import tariff on its OECD partners from the 2014 average of 1.16 percent. Comparing the simulated trade prediction from my model to predictions from a model with exogenous transport costs allows me to quantify the importance of the round trip effect. I first describe the calibration process and then move on to estimation as well as my counterfactual results.

### 6.1 Taking the Model to Data

Tariff rates are taken from the trade-weighted effectively applied tariff rates for manufactures from the World Bank’s World Integrated Trade Solution (WITS) database. Input prices are approximated by hourly manufacturing wages from the OECD following Eaton and Kortum (2002). The use of OECD wages limits the countries in this analysis. Specifically, the lack of comparable manufacturing wages excludes many Asian countries like China and Hong Kong. The round trip marginal cost for each port pair is the sum of the freight rates going both ways (equation (6)).

The price elasticity of demand,  $\sigma$ , is calculated using the trade value demand elas-



ticity from my empirical results. The elasticity of trade value with respect to transport cost predicted by the theory model (equation (7)) is:

$$\frac{\partial X_{ijt}}{\partial T_{ijt}} \frac{T_{ijt}}{X_{ijt}} = (1 - \sigma) \frac{T_{ij}}{w_i \tau_{ij} + T_{ij}} \equiv \alpha \quad (16)$$

This elasticity is equivalent to the estimated demand elasticity in my empirical section,  $\alpha$ . In order to obtain  $\sigma$ , I approximate the freight rate share of price ( $\frac{T_{ij}}{w_i \tau_{ij} + T_{ij}}$ ) with the estimate by Irarrazabal, Moxnes and Opromolla (2015). They calculate that per unit trade cost is about 14 percent of the median price.<sup>29</sup> The price elasticity of demand calculated from equation (16) is 21.7.

This price elasticity of demand estimate, taking into account the endogeneity of transport cost and trade, implies a four- to five-fold increase in my estimates when transport costs are assumed to be exogenous (table 3). This increase is in line with Baier and Bergstrand (2007) who finds a similar five-fold increase in the effect of free trade agreements (FTAs) on trade flows after taking into account of the endogeneity of FTAs. Trefler (1993) estimates a larger ten-fold increase in the impact of nontariff trade barriers (NTBs) when trade protection is modeled endogenously compared to when it is treated as exogenous. Furthermore, both my weight and quality elasticities are in the ballpark of other studies (Clark et al. (2005), Oum, Waters and Yong (1992) as well as Hummels and Skiba (2004)). This gives me confidence that my value elasticity estimate, while larger than typically seen in the literature, is not unreasonable. My results are also robust to a number of alternative specifications.<sup>30</sup>

That being said, there are a few reasons that this estimate could be large. First, there could be potential substitution across months. My data is at the monthly or bimonthly level. If the freight rates for one month increases, an importer could wait until the next month to import their goods. The literature typically estimates these elasticities at the annual level which makes these types of substitution less applicable. In fact, I find that my elasticities decline by at least half when aggregating my estimation to the annual level (table A.9). Steinwender (Forthcoming) finds the same decline in her elasticities when aggregating her daily data as well. Second, there could be potential substitution across US ports (LA/LB, NY, and Houston). If the freight rates out of the Houston port

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<sup>29</sup>It is acknowledged here that per unit trade cost does not just include transport cost but also quotas and per unit tariffs. However, the significance of transport costs has been increasing in recent years due to global decreases in tariffs and other formal trade barriers (Hummels (2007)). As such, I assume here that transport cost make up most of the per unit trade cost.

<sup>30</sup>See the robustness checks in the results section for more details.

increases, an exporter could choose to export out of the New York port. Typically these elasticities are estimated at the country level and these types of substitution would not apply.

The remaining preference parameter and the loading factor are chosen to match the observed trade value and freight rates in my data set given the equilibrium conditions below for each country pair. The preference parameter  $a_{ij}$  captures  $j$ 's preference for  $i$ 's good. The loading factor  $l_{ij}$  captures the average container volume required per quantity of good traded along route  $ij$ . This relaxes the balanced trade quantity assumption in the theory model since both the preference and loading parameters will adjust in order to balance the equilibrium quantity of container volumes between  $i$  and  $j$ , which is the loading factor multiplied by the quantity of goods. The loading factor affects the traded goods price (equation (2)) as well as the profits of the transport firms (equation (5)):

$$p_{ij} = w_j \tau_{ij} + T_{ij} / l_{ij}$$

$$\pi_{i,j} = T_{ij} l_{ij} Q_{ij} + T_{ji} l_{ji} Q_{ji} - c_{ij}^{\tau} \max\{l_{ij} Q_{ij}, l_{ji} Q_{ji}\}$$

where  $Q_{ij}$  is the quantity of goods traded on route  $ij$ . In equilibrium, the container volumes between  $i$  and  $j$  are the same:  $l_{ij} Q_{ij}^* = l_{ji} Q_{ji}^*$ .

The equilibrium freight rates and containerized trade value for route  $ij$ , including loading factors  $l_{ij}$  and  $l_{ji}$ , can be derived from the price and profit functions above as well as the optimality conditions from the theory section (equations (6) and (7)):

$$T_{ij}^* = \frac{l_{ji}}{Y_{ij} + 1} w_j \tau_{ji} + \frac{c_{ij}^{\tau}}{1 + Y_{ij}} - \frac{1}{l_{ij}} \frac{1}{1 + Y_{ji}^{-1}} w_i \tau_{ij}$$

$$X_{ij}^* = p_{ij} Q_{ij} = \left[ \frac{\sigma}{\sigma - 1} \frac{1}{a_{ij}} \right]^{-\sigma} \left[ \frac{1}{1 + Y_{ij}} \left( w_i \tau_{ij} + \frac{l_{ji}}{l_{ij}} \left( w_j \tau_{ji} + c_{ij}^{\tau} \right) \right) \right]^{1-\sigma} \quad (17)$$

$$\text{where } Y_{ij} = \frac{a_{ji}}{a_{ij}} \left( \frac{l_{ji}}{l_{ij}} \right)^{1+1/\sigma}$$

## 6.2 Counterfactual: Doubling US import tariffs

Since my model is just identified, I am able to match the observed freight rates and trade value data exactly. The results below are based on 2014 data. Using my estimated parameters, I construct an out of sample fit for the next year, 2015. I find a positive correlation of 0.6 for trade value and 0.7 for freight rates (figure A.7).

Table 6 shows that trade predictions after doubling US import tariffs on its OECD trading partners from a trade-weighted average of 1.16 percent in 2014. The first two

rows, labeled as “Round Trip”, show predicted percent changes in import and export freight rates, trade price, and trade value for the endogenous transport cost and round trip effect model. The next two rows, labeled as “Exogenous”, show the predicted changes for a model with exogenous transport cost.

The results in table 6 echoes the predictions from Proposition 1. The round trip model predicts that US import freight rates will fall by 0.15 percent to mitigate the US tariff increase. Even though import freight rates are now smaller, US import value and price decreases overall by 2.16 percent and 0.16 percent respectively (Lemma 1). The model with exogenous transport cost predicts a larger decrease in import value (3.68 percent) and price (0.26 percent) since it does not take into account the mitigating effect from transport costs. Furthermore, the round trip effect will generate spillovers from this tariff increase onto US exports. US export freight rates are predicted to increase by 0.18 percent while US export value and price decrease by 0.17 percent and 2.66 percent respectively. The exogenous transport cost model predicts no changes on the export side.

Table 6: Trade Predictions from Doubling US Import Tariff on All Trading Partners

Model		Freight Rate	Trade Price	Trade Value
Round Trip	Import	-0.15%	+0.16%	-2.16%
	Export	+0.18%	+0.17%	-2.66%
Exogenous	Import	0	+0.26%	-3.68%
	Export	0	0	0

Import tariffs are the 2014 trade-weighted effectively applied tariff rates for manufactures. Average import tariff is 1.16 percent with the minimum being 0.09 percent (Australia) and the maximum being 2.68 percent (Turkey). Domestic input prices are approximated by hourly manufacturing wages. Sources: WITS, OECD, Drewry, and USA Trade Online.

From comparing both models, three main observations can be made. First, the exogenous transport cost model predicts no changes in freight rates when US import tariffs are doubled. The round trip model, however, predicts a fall in the import freight rates to mitigate the effects of the tariff increase as well as a rise in export freight rates due to spillovers from the round trip effect. Second, the exogenous transport cost model predicts no changes in export prices and value while the round trip model shows a fall in both prices and value as a result of higher export costs. Third, the exogenous model predicts a larger fall in import trade value and a larger increase in import prices relative to the round trip model. The exogenous model over-predicts the average import value increase by about 41 percent. On average, the exogenous model under-predicts the

average import and export changes by 25 percent. These over- and under-prediction estimates are robust to other trade elasticity estimates as well. Using a trade elasticity of 5, the elasticity suggested by Head and Mayer (2014), the exogenous model still over-predicts the average import value increase by about 40 percent and under-predicts total trade changes by about 18 percent.

These differences in trade predictions have important policy implications. If a country chooses to pursue protectionist policies by increasing their import tariffs, a trade model with exogenous transport cost will first over-predict the level of protection they are affording their local industries—the fall in imports from their trading partners—with no other impact on exports and transport costs. As a result, the exogenous model will predict an increase in the trade balance gap between the country’s exports and imports with all its partners by about 4 percent. However, a model which takes into account endogenous transport costs and the round trip effect will paint a different picture: while the country’s imports fall so will its exports. The country will over-predict its increased level of protection by about 41 percent in value and its overall trade balance will decrease instead by about 0.5 percent.

In order to calculate a tariff equivalent of the round trip effect, I calculate the change in export prices due to increases in US import tariffs. From the proof for Lemma 1 and equation (25) in the Theory Appendix, the derivative of US export prices with respect to US import tariffs is a positive constant. As such, the round trip effect from this model predicts a constant export tax of 0.2 percent on prices when US import tariffs on its partners are increased by a factor of one.

The results from this counterfactual are calculated across 22 port-level routes between the US and its OECD trading partners. Figure 6 shows that this increase in export prices are different across routes, ranging from a 0.01 percent increase for the Melbourne-LA route which has a very low initial US tariff of 0.9 percent to a 0.68 percent increase for the Istanbul-Houston route which has a higher initial tariff of 2.7 percent. Since the counterfactual exercise here increases initial US tariffs by a factor of one, countries with higher US initial tariffs will see a bigger increases in export prices. Conditional upon the port pairs being in the same countries, the differences in export prices are driven by route-specific data and parameters. For example, the Genoa-New York and Genoa-Houston routes have different changes in export prices although the US import tariff for Italy is the same for both routes. US exports on the Genoa-New York route is about 3.5 times more in value compared to US imports, resulting in a

higher export preference parameter relative to imports. This also results in a lower loading factor on the export side relative to imports side. The Genoa-Houston route on the other hand has more US imports relative to exports. These differences mean that the Genoa-New York route has a bigger increase in its export prices than the Genoa-Houston route after US doubles its import tariffs on Italy (equation (17)).

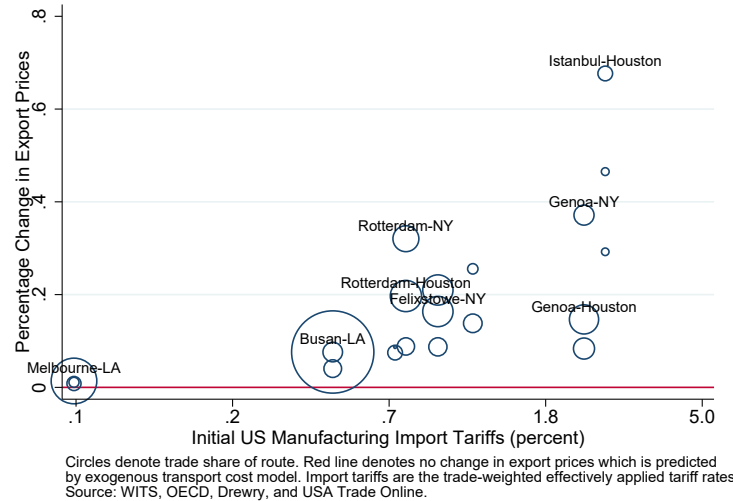


Figure 6: Port-level export price increases from doubling US import tariffs

## 7 Conclusion

This paper provides a microfoundation for transport costs by incorporating one of its key institutional features, the round trip effect. This paper is the first, to my knowledge, to study both the theoretical and empirical implications of the round trip effect for trade outcomes.

I first incorporate a transportation sector with the round trip effect into an Armington trade model. I show that the round trip effect mitigates shocks on a country's trade with its partner and generates spillovers onto its opposite direction trade. This translates a country's import tariffs into a potential tax on its exports with the same partner. This prediction has important policy implications.

Using a novel high frequency bilateral data set on container freight rates, I present descriptive evidence on the round trip effect and its implications for distance and trade between countries. Due to limited availability of port-level freight rates data, this is the first paper to highlight the round trip effect. I provide suggestive empirical evidence

for two main predictions from my theory model: (1) that freight rates are negatively correlated within port pairs, and (2) a country's imports from its partner are positively correlated with its export transport cost to the same partner. The same applies for a country's exports and its import transport cost. Both these correlations indicate the presence of the round trip effect.

I develop an identification strategy utilizing the round trip effect to estimate the containerized trade elasticity with respect to freight rates. I find that a one percent increase in average freight rates will decrease average containerized trade value by 2.8 percent, decrease average containerized trade weight by 3.6 percent, and increase average containerized trade quality by 0.8 percent.

In order to estimate the magnitude of the potential export tax from protectionist policies like import tariffs, I estimate my trade and transportation model using my trade elasticity and simulate a counterfactual where the US doubles its import tariffs on all of its partners from an average of 1.2 percent. I show that this tariff increase will not just decrease US imports but also US exports to these partners. A trade model with exogenous transport costs would over-predict the import decrease by 41 percent, not predict any associated bilateral export decrease at all, and under-predict the total trade changes by 25 percent. Overall, this model predicts an export tax of about 0.2 percent on prices when US import tariffs are doubled.

Future work includes relaxing the perfect competition assumption in the future to study the effects of market power in transportation in the presence of the round trip effect. Concentration in the containership industry has increase over the years through capacity-sharing alliances. However, since there are economies of scale to transportation, these alliances have potential efficiency gains from increased capacity utilization on each ship. Given these factors, it would be worth examining if containership companies should be allowed to form further alliances.

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## A Appendix

### A.1 Simple Model of the Round Trip Effect

There are two transport markets, one going from origin  $j$  to destination  $i$  (*route  $ji$* ) and the other going back from  $i$  to  $j$  (*route  $ij$* ). I present both these markets without the round trip effect and then introduce the round trip effect and its implications.

I assume linear transport demand functions for both routes  $ji$  and  $ij$ :

$$Q_{ji}^D = D^i - d^i T_{ji} \text{ and } Q_{ij}^D = D^j - d^j T_{ij} \quad (18)$$

where  $Q_{ji}^D$  is the transport quantity demanded on route  $ji$  and  $T_{ji}$  is the transport cost, or transport price, on the same route.  $D^i$  is country  $i$ 's demand intercept parameter for transport services from  $j$  ( $D^i > 0$ ) while  $d^i$  is its demand slope parameter ( $d^i > 0$ ). Similar notation applies for the opposite direction variables on route  $ij$ .

#### A.1.1 Model absent the round trip effect

Following the demand assumption, I also assume linear transport supply. Absent the round trip effect, transport supply for both routes are separately determined:

$$\bar{Q}_{ji}^S = C_{ji} + c_{ji} T_{ji} \text{ and } \bar{Q}_{ij}^S = C_{ij} + c_{ij} T_{ij} \quad (19)$$

where  $\bar{Q}_{ji}^S$  is the transport quantity supplied on route  $ji$  and  $T_{ji}$  is the transport cost or price on the same route. Route  $ji$ 's fixed cost of transport supply is  $C_{ji} \geq 0$  (for example, the cost of hiring a captain) and its marginal cost is  $c_{ji} > 0$  (for example, fuel cost). This positive marginal cost generates an upward sloping supply curve.<sup>31</sup>

The equilibrium transport price and quantity for route  $ji$  and  $ij$  are:

$$\begin{aligned} \bar{T}_{ji}^* &= \frac{1}{d^i + c_{ji}} (D^i - C_{ji}) \text{ and } \bar{Q}_{ji}^* = \frac{1}{d^i + c_{ji}} (c_{ji} D^i + d^i C_{ji}) \\ \bar{T}_{ij}^* &= \frac{1}{d^j + c_{ij}} (D^j - C_{ij}) \text{ and } \bar{Q}_{ij}^* = \frac{1}{d^j + c_{ij}} (c_{ij} D^j + d^j C_{ij}) \end{aligned} \quad (20)$$

where any demand and supply parameter changes on a route only affects the transport price and quantity of that route—a positive demand shock on route  $ji$  ( $D^i$  increase) will only affect the route  $ji$  transport price and quantity. Both these markets are illustrated in Panel A of figure A.2. The top graph is the transport market for route  $ji$  while the bottom graph is the transport market for return direction route  $ij$ .

<sup>31</sup>One interpretation is that there are a continuum of small transport firms providing transport between the two countries who face heterogenous marginal costs.

### A.1.2 Model with the round trip effect

In the presence of the round trip effect, transport supply for both routes are jointly determined. For simplicity, I assume that the demand for transport between these two markets are symmetric enough that transport firms will always be at full capacity going between them.<sup>32</sup> As such, the supply of transport on both routes ( $\overleftrightarrow{ij}$ ) will be the same. The combined transport supply for both routes includes the fixed cost of transport ( $C_{\overleftrightarrow{ij}}$ ) and the marginal cost of transport ( $c_{\overleftrightarrow{ij}}$ ):<sup>33</sup>

$$Q_{ij}^S = Q_{ji}^S \equiv Q_{\overleftrightarrow{ij}}^S = C_{\overleftrightarrow{ij}} + c_{\overleftrightarrow{ij}} (T_{ji} + T_{ij}) \quad (21)$$

The equilibrium transport prices and quantity for routes  $ij$  and  $ji$  with the round trip effect are now no longer independently determined:

$$\begin{aligned} T_{ji}^* &= \frac{1}{c_{\overleftrightarrow{ij}}d^i + c_{\overleftrightarrow{ij}}d^j + d^i d^j} \left[ \left( d^j + c_{\overleftrightarrow{ij}} \right) D^i - c_{\overleftrightarrow{ij}} D^j - d^j C_{\overleftrightarrow{ij}} \right] \\ T_{ij}^* &= \frac{1}{c_{\overleftrightarrow{ij}}d^i + c_{\overleftrightarrow{ij}}d^j + d^i d^j} \left[ \left( d^i + c_{\overleftrightarrow{ij}} \right) D^j - c_{\overleftrightarrow{ij}} D^i - d^i C_{\overleftrightarrow{ij}} \right] \\ Q_{ji}^* = Q_{ij}^* &\equiv Q^* = \frac{C_{\overleftrightarrow{ij}}}{c_{\overleftrightarrow{ij}}d^i + c_{\overleftrightarrow{ij}}d^j + d^i d^j} + \frac{D^i}{\left( d^j + c_{\overleftrightarrow{ij}} \right) d^i} + \frac{D^j}{\left( d^i + c_{\overleftrightarrow{ij}} \right) d^j} \end{aligned} \quad (22)$$

where the equilibrium transport price on route  $ji$  ( $T_{ji}^*$ ) is increasing in destination country  $i$ 's demand intercept for  $j$  ( $D^i$ ) but decreasing in the fixed cost of round trip transport ( $C_{\overleftrightarrow{ij}}$ ). Additionally, it is now a function of the origin country  $i$ 's demand parameters: it is decreasing in the origin country  $j$ 's demand intercept for  $i$ 's good ( $D^j$ ). This latter prediction is due to the round trip effect. The same applies for the transport price on route  $ij$  ( $T_{ij}^*$ ). The equilibrium quantity of transport services for both routes is increasing in the demand intercepts in both countries ( $D^i$  and  $D^j$ ) and the round trip fixed cost of transport ( $C_{\overleftrightarrow{ij}}$ ) but decreasing in both countries' demand slopes and the round trip marginal cost ( $c_{\overleftrightarrow{ij}}$ ).

Both the transport markets for routes  $ji$  and  $ij$  are illustrated in Panel B of figure A.2. In the presence of the round trip effect, both these markets are now linked via transport supply and the equilibrium transport quantity is the same.

Now suppose there is a positive demand shock on route  $ji$  where  $i$ 's demand for  $j$ 's

<sup>32</sup>If demand between these markets are asymmetric enough, there may be some transport firms going empty one way (Ishikawa and Tarui (2016)). Potential modeling modifications can and have been made in order to accommodate this feature, for example a search framework. The theory section and online appendix B elaborates.

<sup>33</sup>These costs are assumed to be the same here. It is possible to relax this assumption without changing the main results.

good( $D^i$ ) increases while holding the other parameters constant. This raises the equilibrium transport price on route  $ji$  (equation (22)) as well as the equilibrium transport quantity. Through the round trip effect, the equilibrium quantity on opposite route  $ij$  also increases. Since the demand on opposite route  $ij$  has not changed, this increased transport quantity decreases its transport price (equation (22)). As such, in the presence of the round trip effect, a positive demand shock on route  $ji$  does not just increase the equilibrium transport price and quantity on that route, it also decreases the equilibrium transport price on the opposite route  $ij$ . The blue lines in Panel B of figure A.2 illustrates this demand shock graphically where  $Q_{ji}^D$  is the new demand curve after the shock on  $i$ 's demand intercept for  $j$  ( $\hat{D}^i > D^i$ ).  $Q_{ij}^S$  is the new transport supply on opposite route  $ij$  which results in a lower equilibrium transport price  $T_{ij}^{/*}$ .<sup>34</sup>

## A.2 Theory Appendix

### Endogenous Transport Cost & Round Trip Effect Model: Symmetric Equilibrium

In the special case where countries  $i$  and  $j$  are symmetric, the preference parameters in both countries would be the same:  $a_{ij} = a_{ji} \equiv a$ . As such, the freight rates each way between  $i$  and  $j$  will be the same—one half of the round trip marginal cost:  $T_{ij}^{Sym} = T_{ji}^{Sym} = \frac{1}{2}c_{ij}^{\leftarrow}$ . The symmetric equilibrium prices, quantities, and values are a function of the domestic wages and tariffs in both countries as well as the round trip marginal cost:

$$\begin{aligned} p_{ij}^{Sym} &= p_{ji}^{Sym} = \frac{1}{2} \left( w_j \tau_{ji} + w_i \tau_{ij} + c_{ij}^{\leftarrow} \right) \\ q_{ij}^{Sym} &= q_{ji}^{Sym} = \left[ \frac{\sigma}{\sigma-1} \frac{1}{a} \frac{1}{2} \left( w_j \tau_{ji} + w_i \tau_{ij} + c_{ij}^{\leftarrow} \right) \right]^{-\sigma} \\ X_{ij}^{Sym} &= X_{ji}^{Sym} = \left[ \frac{\sigma}{\sigma-1} \frac{1}{a} \right]^{-\sigma} \left[ \frac{1}{2} \left( w_j \tau_{ji} + w_i \tau_{ij} + c_{ij}^{\leftarrow} \right) \right]^{1-\sigma} \end{aligned} \quad (23)$$

### Endogenous Transport Cost & Round Trip Effect Model: Opposite Direction Equilibrium

The equilibrium freight rate for route  $ji$  is

$$T_{ji}^R = \frac{1}{1+A_{ji}} \left( w_i \tau_{ij} + c_{ij}^{\leftarrow} \right) - \frac{1}{1+A_{ji}^{-1}} \left( w_j \tau_{ji} \right), \quad A_{ji} = \frac{a_{ij}}{a_{ji}} \quad (24)$$

<sup>34</sup>The new lower opposite route transport price  $T_{ij}^{/*}$  will also shift the route  $ji$  supply ( $Q_{ji}^S$ , equation (21)).

The equilibrium trade price, quantity, and value of country  $j$ 's good in  $i$  is

$$\begin{aligned}
p_{ji}^R &= \frac{1}{1+A_{ji}} \left( w_i \tau_{ij} + w_j \tau_{ji} + c_{ij}^{\tau} \right) \\
q_{ji}^R &= \left[ \frac{\sigma}{\sigma-1} \frac{1}{a_{ji}} \frac{1}{1+A_{ji}} \left( w_i \tau_{ij} + w_j \tau_{ji} + c_{ij}^{\tau} \right) \right]^{-\sigma} \\
X_{ji}^R &= \left[ \frac{\sigma}{\sigma-1} \frac{1}{a_{ji}} \right]^{-\sigma} \left[ \frac{1}{1+A_{ji}} \left( w_i \tau_{ij} + w_j \tau_{ji} + c_{ij}^{\tau} \right) \right]^{1-\sigma} \\
\text{where } A_{ji} &= \frac{a_{ij}}{a_{ji}}
\end{aligned} \tag{25}$$

**Proof of Lemma 1** This lemma can be proven via direct calculation. In the exogenous transport cost model, the derivative of  $j$ 's import price from  $i$  with respect to its import tariff on  $i$  is positive (equation (3)):  $\frac{\partial p_{ij}^{Exo}}{\partial \tau_{ij}} = w_i > 0$ . From equation (4), the derivative of  $j$ 's import quantity from  $i$  with respect to its import tariff on  $i$  is negative:  $\frac{\partial q_{ij}^{Exo}}{\partial \tau_{ij}} = -\sigma w_i (w_i \tau_{ij} + c_{ij})^{-\sigma-1} \left[ \frac{\sigma}{\sigma-1} \frac{1}{a_{ij}} \right]^{-\sigma} < 0$ . From equation (4), the derivative of  $j$ 's import quantity from  $i$  with respect to its import tariff on  $i$  is also negative:  $\frac{\partial X_{ij}^{Exo}}{\partial \tau_{ij}} = -(\sigma-1) w_i (w_i \tau_{ij} + c_{ij})^{-\sigma} \left[ \frac{\sigma}{\sigma-1} \frac{1}{a_{ij}} \right]^{-\sigma} < 0$ .

In the endogenous transport cost model with the round trip effect, an increase in  $j$ 's import tariff on  $i$  decreases  $j$ 's import transport cost from  $i$ . The derivative of the transport cost from  $i$  to  $j$  with respect to  $j$ 's import tariff on  $i$  is negative (equation (9)):  $\frac{\partial T_{ij}^R}{\partial \tau_{ij}} = -\frac{1}{1+A_{ij}} w_i < 0$ .

The increase in  $j$ 's import tariff on  $i$  will also decrease the price of  $j$ 's imports from  $i$  through its import transport cost decrease. The derivative of the price of country  $i$ 's good in country  $j$  with respect to  $j$ 's import tariff on  $i$  is positive (equation (10)) and the same magnitude as the the derivative of the transport cost from  $i$  to  $j$  with respect to  $j$ 's import tariff on  $i$ :  $\frac{\partial p_{ij}^R}{\partial \tau_{ij}} = \frac{1}{1+A_{ij}} w_i > 0$ .

Country  $j$ 's equilibrium import quantity from  $i$  will decrease with the increase of  $j$ 's import tariff on  $i$ , as does its equilibrium trade value from  $i$ . From equation (11), the derivative of the trade quantity from  $i$  to  $j$  with respect to  $j$ 's import tariff on  $i$  is negative:  $\frac{\partial q_{ij}^R}{\partial \tau_{ij}} = -\sigma w_i \left( \frac{\sigma}{\sigma-1} \frac{1}{a_{ij}} \left( \frac{1}{1+A_{ij}} \right) \right)^{-\sigma} \left( w_j \tau_{ji} + w_i \tau_{ij} + c_{ij}^{\tau} \right)^{-\sigma-1} < 0$ . From equation (11), the derivative of the trade value from  $i$  to  $j$  with respect to  $j$ 's import tariff on  $i$  is negative:  $\frac{\partial X_{ij}^R}{\partial \tau_{ij}} = -(\sigma-1) w_i \left( \frac{1}{1+A_{ij}} \right)^{1-\sigma} \left[ \frac{\sigma}{\sigma-1} \frac{1}{a_{ij}} \left( w_j \tau_{ji} + w_i \tau_{ij} + c_{ij}^{\tau} \right) \right]^{-\sigma} < 0$ .

The mitigating effects from the endogenous transport cost and round trip effect model is clear when comparing the import trade changes between the two models. The

import quantity fall due to tariffs for the exogenous transport cost model is larger:

$$\frac{\partial q_{ij}^{Exo} / \partial \tau_{ij}}{\partial q_{ij}^R / \partial \tau_{ij}} = \frac{(w_i \tau_{ij} + c_{ij})^{-\sigma-1}}{\frac{1}{1+A_{ij}} (w_i \tau_{ij} + w_j \tau_{ji} + c_{ij}^*)^{-\sigma-1}} > 0$$

The same can be shown for the import value fall between the models:

$$\frac{\partial X_{ij}^{Exo} / \partial \tau_{ij}}{\partial X_{ij}^R / \partial \tau_{ij}} = \frac{(w_i \tau_{ij} + c_{ij})^{-\sigma}}{\left(\frac{1}{1+A_{ij}}\right)^{1-\sigma} (w_i \tau_{ij} + w_j \tau_{ji} + c_{ij}^*)^{-\sigma}} > 0$$

Due to the round trip effect, an increase in  $j$ 's import tariff on  $i$  also affects  $j$ 's exports to  $i$ . First,  $j$ 's export transport cost to  $i$  increases in order to compensate for the fall in inbound transport demand from  $i$  to  $j$ . The derivative of the transport cost from  $j$  to  $i$  with respect to  $j$ 's import tariff on  $i$  is positive (equation (24)):  $\frac{\partial T_{ji}^R}{\partial \tau_{ij}} = \frac{1}{1+A_{ij}^{-1}} w_i > 0$ . Unlike the comparative statics involving  $j$ 's preference of  $i$ 's goods, the amount of decrease in  $j$ 's import transport cost from  $i$  is no longer the same as the amount of increase in  $j$ 's export transport cost to  $i$ .

The increase in  $j$ 's import tariff on  $i$  also increases  $j$ 's export price to  $i$ . The derivative of  $j$ 's export price to  $i$  with respect to  $j$ 's import tariff on  $i$  is positive (equation (25)):  $\frac{\partial p_{ji}^R}{\partial \tau_{ij}} = \frac{1}{1+A_{ij}^{-1}} w_i > 0$ . This export price increase is the same amount as  $j$ 's import transport cost increase.

Lastly, the increase in  $j$ 's import tariff on  $i$  decreases  $j$ 's export quantity and value to  $i$ . The derivative of  $j$ 's export quantity to  $i$  with respect to  $j$ 's import tariff on  $i$  is negative (equation (25)):  $\frac{\partial q_{ji}^R}{\partial \tau_{ij}} = -\sigma w_i \left(\frac{\sigma}{\sigma-1} \frac{1}{a_{ji}} \left(\frac{1}{1+A_{ij}^{-1}}\right)\right)^{-\sigma} (w_j \tau_{ji} + w_i \tau_{ij} + c_{ij}^*)^{-\sigma-1} < 0$ . The derivative of  $j$ 's export value to  $i$  with respect to  $j$ 's preference for  $i$ 's good is negative (equation (25)):  $\frac{\partial X_{ji}^R}{\partial \tau_{ij}} = -(\sigma-1) w_i \left(\frac{1}{1+A_{ij}^{-1}}\right)^{1-\sigma} \left[\frac{\sigma}{\sigma-1} \frac{1}{a_{ji}} (w_j \tau_{ji} + w_i \tau_{ij} + c_{ij}^*)\right]^{-\sigma} < 0$ .

**Proof of Lemma 2** This lemma can be proven via direct calculation. In the exogenous transport cost model, the derivative of  $j$ 's import quantity from  $i$  with respect to  $j$ 's preference for  $i$ 's good is positive (equation (4)):  $\frac{\partial q_{ij}^{Exo}}{\partial a_{ij}} = \sigma a_{ij}^{\sigma-1} \left[\frac{\sigma}{\sigma-1} (w_i \tau_{ij} + c_{ij})\right]^{-\sigma} > 0$ . The derivative of  $j$ 's import value from  $i$  with respect to  $j$ 's preference for  $i$ 's good is also positive (equation (4)):  $\frac{\partial X_{ij}^{Exo}}{\partial a_{ij}} = \sigma a_{ij}^{\sigma-1} \left(\frac{\sigma}{\sigma-1}\right)^{-\sigma} (w_i \tau_{ij} + c_{ij})^{1-\sigma} > 0$ . Country  $j$ 's import price from  $i$  does not change with its preference for  $i$ 's good (equation (3)):

$$\frac{\partial p_{ij}^{Exo}}{\partial a_{ij}} = 0.$$

In the endogenous transport cost and round trip effect model, I first establish that the derivative of the loading factor and preference ratio from  $i$  to  $j$  with respect to  $j$ 's preference for  $i$ 's good is negative,  $\frac{\partial A_{ij}}{\partial a_{ij}} = -\frac{1}{a_{ij}}A_{ij} < 0$ . The derivative of the loading factor and preference ratio from  $j$  to  $i$  with respect to  $j$ 's preference for  $i$ 's good is positive,  $\frac{\partial A_{ji}}{\partial a_{ij}} = \frac{1}{a_{ij}}A_{ij}^{-1} > 0$ .

An increase in  $j$ 's preference for  $i$ 's good increases  $j$ 's import transport cost from  $i$ . The derivative of the transport cost from  $i$  to  $j$  with respect to  $j$ 's preference for  $i$ 's good is positive (equation (9)):  $\frac{\partial T_{ij}^R}{\partial a_{ij}} = \frac{1}{a_{ij}} \frac{1}{1+A_{ij}} \frac{1}{1+A_{ij}^{-1}} [w_i \tau_{ij} + w_j \tau_{ji} + c_{ij}^*] > 0$ .

The increase in  $j$ 's preference for  $i$ 's good will also increase the price of  $j$ 's imports from  $i$  through the increase in  $j$ 's import transport cost from  $i$ . The derivative of the price of country  $i$ 's good in country  $j$  with respect to  $j$ 's preference for  $i$ 's good is positive (equation (10)) and the same as the the derivative of the transport cost from  $i$  to  $j$  with respect to  $j$ 's preference for  $i$ 's good:  $\frac{\partial P_{ij}^R}{\partial a_{ij}} = \frac{1}{a_{ij}} \frac{1}{1+A_{ij}} \frac{1}{1+A_{ij}^{-1}} [w_i \tau_{ij} + w_j \tau_{ji} + c_{ij}^*] > 0$ .

Even though the increase in  $j$ 's preference for  $i$  raises the price of its imports from  $i$ ,  $j$ 's equilibrium import quantity from  $i$  still increases as does its equilibrium trade value from  $i$ . From equation (11), the derivative of the trade quantity from  $i$  to  $j$  with respect to  $j$ 's preference for  $i$ 's good is positive:  $\frac{\partial q_{ij}^R}{\partial a_{ij}} = \sigma \left(\frac{1}{a_{ij}}\right)^{1-\sigma} \left(\frac{1}{1+A_{ij}}\right)^{1-\sigma} \left[\frac{\sigma}{\sigma-1} (w_j \tau_{ji} + w_i \tau_{ij} + c_{ij}^*)\right]^{-\sigma} > 0$ . From equation (11), the derivative of the trade value from  $i$  to  $j$  with respect to  $j$ 's preference for  $i$ 's good is positive:  $\frac{\partial X_{ij}^R}{\partial a_{ij}} = (\sigma + A_{ij}) \left(\frac{1}{a_{ij}}\right)^{1-\sigma} \left(\frac{1}{1+A_{ij}}\right)^{2-\sigma} \left[\frac{\sigma}{\sigma-1}\right]^{-\sigma} (w_j \tau_{ji} + w_i \tau_{ij} + c_{ij}^*)^{1-\sigma} > 0$ .

The mitigating effects from the endogenous transport cost and round trip effect model is clear when comparing the import trade changes between the two models. The import quantity increase in the exogenous transport cost model is larger than the endogenous model:

$$\frac{\partial q_{ij}^{Exo} / \partial a_{ij}}{\partial q_{ij}^R / \partial a_{ij}} = \frac{(w_i \tau_{ij} + c_{ij})^{-\sigma}}{\left(\frac{1}{1+A_{ij}}\right)^{1-\sigma} (w_i \tau_{ij} + w_j \tau_{ji} + c_{ij}^*)^{-\sigma}} > 0$$

The same can be shown for the import value increase between the models:

$$\frac{\partial X_{ij}^{Exo} / \partial a_{ij}}{\partial X_{ij}^R / \partial a_{ij}} = \frac{\sigma (w_i \tau_{ij} + c_{ij})^{1-\sigma}}{(\sigma + A_{ij}) \left(\frac{1}{1+A_{ij}}\right)^{2-\sigma} (w_i \tau_{ij} + w_j \tau_{ji} + c_{ij}^*)^{1-\sigma}} > 0$$

Due to the round trip effect, an increase in  $j$ 's preference of  $i$ 's good also affects  $j$ 's

exports to  $i$ . First,  $j$ 's export transport cost to  $i$  decreases in order to compensate for the increase in inbound transport demand from  $i$  to  $j$ . The derivative of the transport cost from  $j$  to  $i$  with respect to  $j$ 's preference for  $i$ 's good is negative (equation (24)):  $\frac{\partial T_{ji}^R}{\partial a_{ij}} = -\frac{1}{a_{ij}} \frac{1}{1+A_{ij}} \frac{1}{1+A_{ij}^{-1}} \left[ w_i \tau_{ij} + w_j \tau_{ji} + c_{ij}^{\leftarrow} \right] < 0$ . The amount of increase in  $j$ 's import transport cost from  $i$  is the same as the amount of decrease in  $j$ 's export transport cost to  $i$ .

The increase in  $j$ 's preference of  $i$ 's good also decreases  $j$ 's export price to  $i$ . The derivative of  $j$ 's export price to  $i$  with respect to  $j$ 's preference for  $i$ 's good is negative (equation (25)):  $\frac{\partial p_{ji}^R}{\partial a_{ij}} = -\frac{1}{a_{ij}} \frac{1}{1+A_{ij}} \frac{1}{1+A_{ij}^{-1}} \left[ w_i \tau_{ij} + w_j \tau_{ji} + c_{ij}^{\leftarrow} \right] < 0$ . This export price decrease is the same amount as  $j$ 's import price increase due to the same amount of  $j$ 's export and import transport cost changes.

Lastly, the increase in  $j$ 's preference of  $i$ 's good increases  $j$ 's export quantity and value to  $i$ . The derivative of  $j$ 's export quantity to  $i$  with respect to  $j$ 's preference for  $i$ 's good is positive (equation (25)):  $\frac{\partial q_{ji}^R}{\partial a_{ij}} = \sigma \frac{1}{a_{ij}} \frac{1}{1+A_{ij}} \left( \frac{1}{1+A_{ij}^{-1}} \right)^{-\sigma} \left[ \frac{\sigma}{\sigma-1} \frac{1}{a_{ji}} \left( w_j \tau_{ji} + w_i \tau_{ij} + c_{ij}^{\leftarrow} \right) \right]^{-\sigma} > 0$ . The derivative of  $j$ 's export value to  $i$  with respect to  $j$ 's preference for  $i$ 's good is positive (equation (25)):  $\frac{\partial X_{ji}^R}{\partial a_{ij}} = (\sigma - 1) \frac{1}{a_{ij}} \frac{1}{1+A_{ij}} \left( \frac{1}{1+A_{ij}^{-1}} \right)^{1-\sigma} \left[ \frac{\sigma}{\sigma-1} \frac{1}{a_{ji}} \right]^{-\sigma} \left( w_j \tau_{ji} + w_i \tau_{ij} + c_{ij}^{\leftarrow} \right)^{1-\sigma} > 0$ .

## A.3 Data Appendix

### A.3.1 Container freight rates

These monthly or bimonthly Drewry spot market rates are for a full container sized at either 20 or 40 feet. In this study I focus only on 20 feet containers. These containers are for dry freight, which means that they do not need to be refrigerated. Breakdowns are also available for some of these freight rates. They include the base ocean rate, the terminal handling charge at the origin and destination ports, and the bunker fuel surcharge.

The container freight rates, published by Drewry Maritime Research, as well as the containerized trade value, published by USA Trade Online, were converted into real terms using the seasonally adjusted Consumer Price Index for all urban consumers published by the Bureau of Labor Statistics (series ID CPIAUCSL).

The port pairs in my Drewry data set are between the three US ports (New York, Houston, Los Angeles and Long Beach) and the following ports: Australia (Melbourne), Brazil (Santos), Central China (Shanghai), Hong Kong, India (Nhava Sheva), Japan (Yokohama), Korea (Busan), Malaysia (Tanjung Pelepas), New Zealand (Auck-



land), North China (Tianjin), North Continent Europe (Rotterdam), Philippines (Manila), Russia (St Petersburg), Singapore, South Africa (Durban), South China (Yantian), Taiwan (Kaohsiung), Thailand (Laem Chabang), Turkey (Istanbul), U.A.E (Jebel Ali), UK (Felixstowe), Vietnam (Ho Chi Minh), and West Med (Genoa)

Since the freight rate data is at the port level while the containerized trade data is at the US-port and foreign country level, I have some non-US port pairs in the same country that are redundant. In these cases, I chose the freight rates from the port with the longest time series. One example is US and China freight rates. Drewry collects data on the freight rates between the port of New York and South China (Yantian), Central China (Shanghai), and North China (Tianjin). However, I only observe the containerized trade between the port of New York and China from USA Trade Online. In such cases, I choose the freight rate with the longest time series—in this case South China (Yantian).

According to Drewry, their freight rate data set can be applied to adjacent container ports as well. I have not done this. An example is the port of Rotterdam. Since this port is in the Netherlands, I have matched the freight rates to and from this port to the US containerized trade data with Netherlands. However, this port represents the Drewry’s “Hamburg-Le Havre range” which includes Antwerp (Belgium), Rotterdam, Le Havre (France), Hamburg (Germany), Zeebrugge (Belgium), and Bremerhaven (Germany). As such, I could have also matched these freight rates to US trade with Belgium, France, and Germany. Another example is the port of Genoa is Drewry’s benchmark for the (Western) Mediterranean region which includes Valencia and Barcelona (Spain). I could have also matched the Genoa freight rates to US trade with Italy as well as Spain. I choose to restrict my data set initially and match the freight rates literally to the country where their ports are in.

While it is acknowledged here that long-term contracts are used in the container market, my choice to use spot container freight rates instead is due to the fact that long-term container contracts are confidentially filed with the Federal Maritime Commission (FMC) and protected against the Freedom of Information Act (FOIA). I filed a FOIA request with the FMC on April 2015 for long-term container contracts. It was rejected on June 2015. According to the rejection, the information I seek is prohibited from disclosure by the Shipping Act, 46 U.S.C. §40502(b)(1). This information is being withheld in full pursuant to Exemption 3, 5 U.S.C. §552(b)(3) of the FOIA which allows the withholding of information prohibited from disclosure by another federal

statute. Moreover, some industry experts have explained that shorter-term contracts are increasingly favored due to over-capacity in the market.<sup>35</sup> Longer term contracts are also increasingly indexed to spot market rates due to price fluctuations.<sup>36</sup> Furthermore, most firms split their cargo between long-term contracts and the spot market to smooth volatility and take advantage of spot prices. There are freight forwarders, forwarding companies like UPS or FedEx, who offer hybrid models that allow for their customers to switch to spot rate pricing when spot rates fall below their agreed-upon contract rates.<sup>37</sup> As such, I conclude that spot prices play a big role in informing long-term contracts and can shed light on the container transport market.

### **A.3.2 Container volume data**

The container volume data from United States Maritime Administration (MARAD) comes from the Port Import Export Reporting Service (PIERS) provided by the IHS Markit. It may include loaded and empty containers which have an associated freight charge. Since transport firms do not charge to re-position their own containers, these are newly manufactured containers bought by other firms. In order to remove empty containers from this data set, I utilize the product-level containerized trade data from USA Trade Online. The HS6 product code for containers are 860900. Since I observe the trade weight of these containers, I can calculate the number of newly manufactured containers by assuming an empty TEU container weight of 2300kg. I then subtract these new containers from the MARAD container volume data.

This data set is much more aggregated than my matched freight rates and containerized value/weight data—it is at the country and annual level—so it requires that I aggregate my data set, which drastically reduces the number of my observations. In order to do this, I use the annual total US containerized imports and exports trade and the average of container freight rates for the different US ports.

Table A.1 presents the summary statistics of the aggregated data set. The translation of containerized trade into number of containers can be shown where the average number of containers, measured as a unit capacity of a container ship (Twenty Foot Equivalent Unit, TEU), are higher for US imports than exports (table A.1). With the number of containers, I can calculate the average value and weight per container. The

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<sup>35</sup>Conversation with Roy J. Pearson, Director, Office of Economics & Competition Analysis at the Federal Maritime Commission, January 2015.

<sup>36</sup>Container Rate Indexes Run in Contracts, But Crawl in Futures Trading, [Journal of Commerce, January 2014](#)

<sup>37</sup>Container lines suffer brutal trans-Pacific contract season, [Journal of Commerce, June 2016](#).

average value per container and weight per container for US imports is higher than exports. The larger ratio between the import and export value per container compared to weight per container is in line with the value per weight statistics where higher quality goods are being imported by the US versus exported.

In the last row of table A.1, I calculate the ad-valorem equivalent of freight rates by dividing it with the value per container. The average iceberg cost for container freight rates is 8%.<sup>38</sup> The iceberg cost for US imports at 9% is higher than the iceberg cost for US exports at 6%. However, this variable belies two endogenous components: freight rates and trade value. Container freight rates and containerized trade value are jointly determined since they are market outcomes. This paper will study the freight rate and value variables as such.

### **A.3.3 Containerized trade data**

Containerized trade data is from USA Trade Online. The containerized import value data excludes US import duties, freight, insurance and other charges incurred in bringing the merchandise to the US. The containerized exports value data are valued on a free alongside ship (FAS) basis, which includes inland freight, insurance and other charges incurred in placing the merchandise alongside the ship at the port of export. The containerized shipping weight data represents the gross weight in kilograms of shipments, including the weight of moisture content, wrappings, crates, boxes, and containers.

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<sup>38</sup>This average measure is in the ballpark with the 6.7% container freight per value average in Rodrigue, Comtois and Slack (2013).

## A.4 Additional Tables and Figures

Figure A.1: Positive correlation between container volume gap and freight rate gap between countries

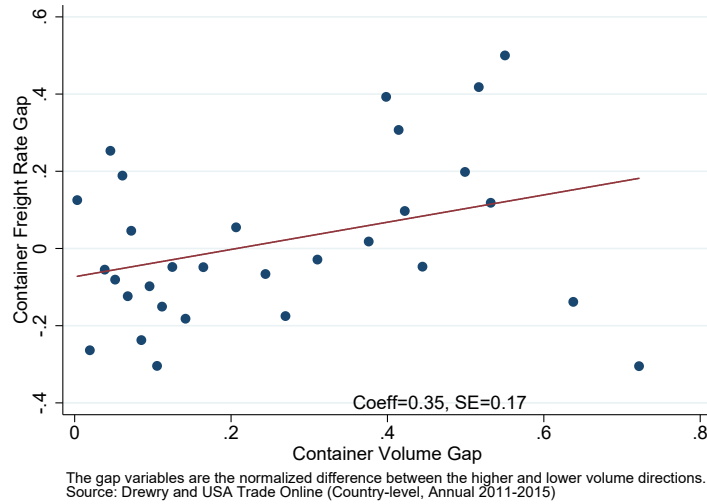
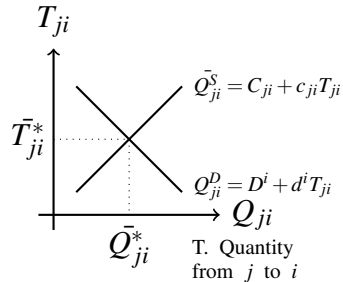


Figure A.2: Transport markets between countries  $i$  and  $j$  in the absence (Panel A) and presence (Panel B) of the round trip effect

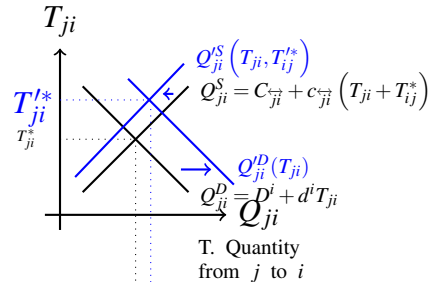
Panel A: Without the Round Trip Effect

Panel B: With the Round Trip Effect

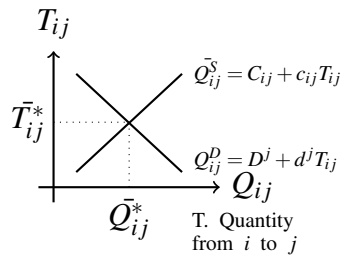
T. Cost (Price) from  $j$  to  $i$



T. Cost (Price) from  $j$  to  $i$



T. Cost (Price) from  $i$  to  $j$



T. Cost (Price) from  $i$  to  $j$

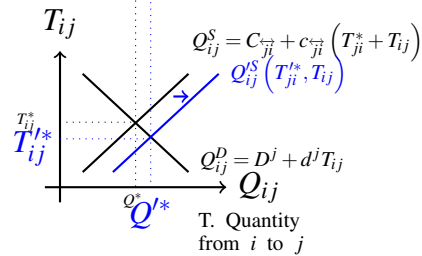


Figure A.3: Containerized trade value and weight ( $X_{ijt}$ ) are positively correlated with container volume ( $Q_{jit}$ ) within routes

$$\ln X_{ijt} = \beta_0 + \beta_1 \ln Q_{jit} + d_{ij}^* + \gamma_t + \varepsilon_{ijt}$$

Panel A: Trade Value

Panel B: Trade Weight

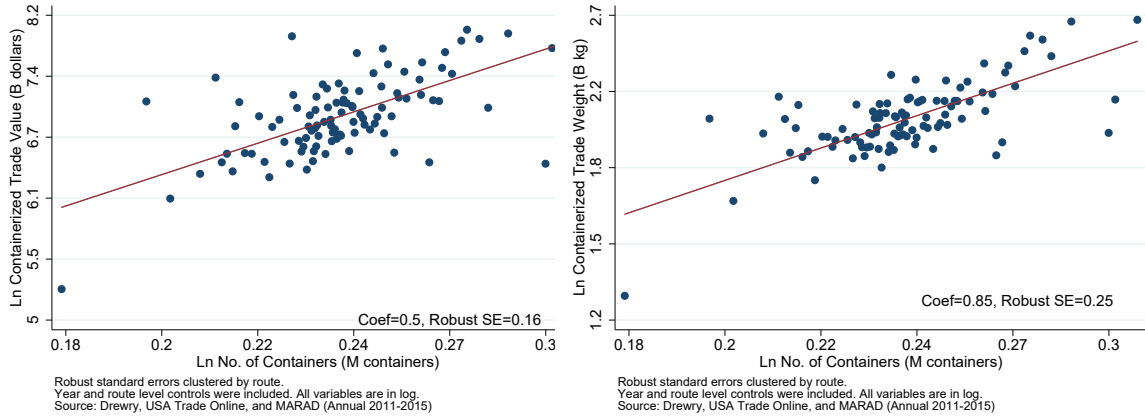


Table A.1: Summary Statistics of aggregate data set matched with container volumes per year

	US Exports	US Imports	Full Sample
Containers (TEU)	387,345 (583,175)	725,741 (1,918,346)	556,543 (1,424,442)
Value per TEU	25,138 (10,273)	41,280 (19,368)	33,209 (17,453)
Weight per TEU	8,956 (1,665)	10,549 (7,507)	9,753 (5,483)
Iceberg Cost	.062 (.03)	.091 (.15)	.076 (.11)
Observations	103	103	206

Standard deviation in parentheses. There are two levels of aggregation: (1) port-level aggregated up to country-level and (2) monthly aggregated up to yearly. Iceberg cost is the ratio of freight rates to value per container ( $\frac{\text{Freight Rates}}{\text{Value per TEU}}$ ).

Sources: Drewry, Census Bureau, and MARAD (Yearly 2011-2015).

Table A.2: Regression of container freight rate within port-pairs

	(1)	(2)
	In Freight Rates	In Freight Rates
In Opposite Dir FR	-0.205* (0.0778)	-0.814*** (0.0202)
In Distance	0.587*** (0.0718)	
Observations	4033	4033
Route FE		Y
Time FE	Y	Y
$R^2$	0.235	0.818
F	34.52	1620.6

Route-level clustered standard errors (SE) in parentheses.

\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

(1) has distance and time controls while (2) has route and time controls.

Sources: Drewry and sea-distances.org (Monthly 2006-Jun 2016)

Figure A.4: Tariff rates are mostly constant for country pairs during my sample period

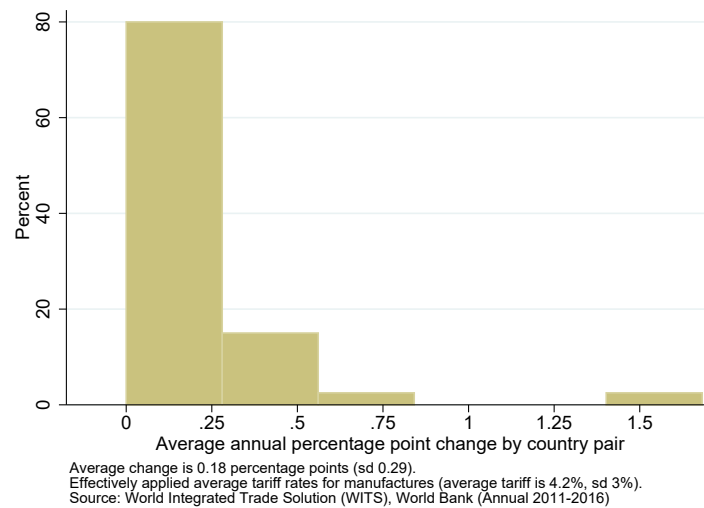


Figure A.5: First stage regression results

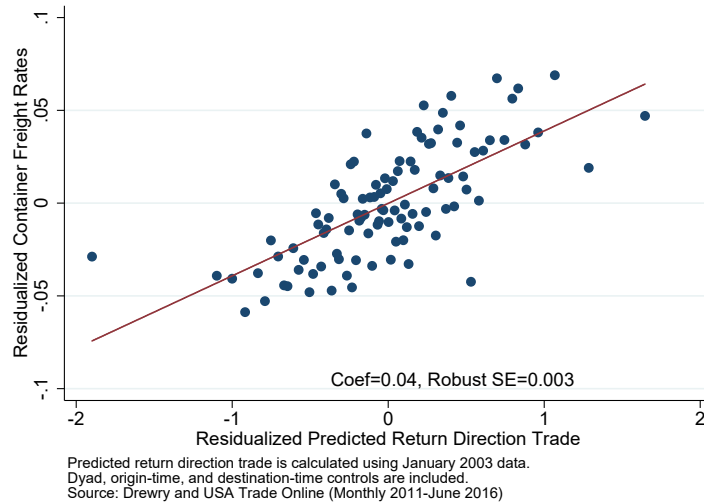


Table A.3: First-Stage Regressions of Containerized Trade Demand Estimates for OECD countries (table 3)

	(1)	(2)
	ln Freight Rate	ln Freight Rate
In Opp Dir Predicted Trade Value	0.0406** (0.0115)	0.0370** (0.0113)
Ex-Time & Im-Time FE	Y	Y
Dyad FE	Y	
Product FE	Y	
Dyad-Product FE		Y
Observations	116887	116887
$R^2$	0.970	0.972
F	12.38	10.70

Robust standard errors in parentheses are clustered by route.

\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

Results are robust to clustering at the route and product, dyad (two-way route), and dyad with products level. All variables are in logs. Trade outcome is aggregated to the HS2 level. The predicted trade instrument is constructed at the HS4 level with Jan 2003 data using only OECD countries.

Fixed Effects explanation: Ex-Time FE is exporter country and time fixed effects; Im-Time FE is importer country and time fixed effects.

Sources: Drewry and USA Trade Online (Monthly 2011-June 2016)

Table A.4: First-Stage Regressions of Containerized Trade Demand Estimates for All Countries (table 4)

	(1)	(2)
	ln Freight Rate	ln Freight Rate
In Opp Dir Predicted Trade Value	0.0227** (0.00781)	0.0227** (0.00817)
Ex-Time & Im-Time FE	Y	Y
Dyad FE	Y	
Product FE	Y	
Dyad-Product FE		Y
Observations	261249	261249
$R^2$	0.973	0.975
F	8.433	7.750

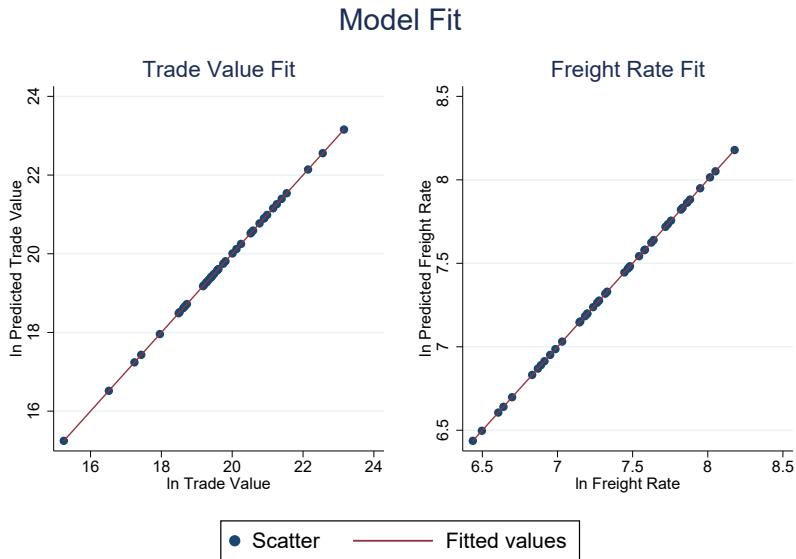
Robust standard errors in parentheses are clustered by route.

\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

Results are robust to clustering at the route and product, dyad (two-way route), and dyad with products level. All variables are in logs. Trade outcome is aggregated to the HS2 level. The predicted trade instrument is constructed at the HS4 level with Jan 2003 data using only OECD countries. Second stage is run on all countries.

Fixed Effects explanation: Ex-Time FE is exporter country and time fixed effects; Im-Time FE is importer country and time fixed effects.

Sources: Drewry and USA Trade Online (Monthly 2011-June 2016)



22 US port-country routes. Corr = 1 for both graphs



Table A.5: Containerized Trade Value Demand Estimates using Aggregate Data for OECD Countries

	(1)	(2)	(3)
	OLS	IV	First-Stage
<b>Panel A: ln Trade Value</b>			
ln Freight Rate	-0.132 (0.307)	-4.137** (1.506)	
ln Opp Dir Predicted Trade Value			0.0391** (0.0138)
<b>Panel B: ln Trade Weight</b>			
ln Freight Rate	-0.415 (0.464)	-6.319** (2.205)	
ln Opp Dir Predicted Trade Value			0.0391** (0.0138)
Ex-Time & Im-Time FE	Y	Y	Y
Dyad FE	Y	Y	Y
Observations	2307	2307	2307

Robust standard errors in parentheses are clustered by route. Results are robust to clustering at the dyad level. \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

All variables are in logs. Trade value and weight are aggregated to route level. The predicted trade instrument is constructed at the HS4 level with Jan 2003 data using only OECD countries. Second stage is run on OECD countries only as well. First stage F is 7.5 for Panel A and 8.2 for Panel B.

Fixed Effects explanation: Ex-Time FE is exporter country and time fixed effects; Im-Time FE is importer country and time fixed effects.

Sources: Drewry and USA Trade Online (Monthly 2011-June 2016)

Table A.6: First-Stage Regressions of Containerized Trade Demand Estimates for All Countries without Fragmented Products (table 5)

	(1)	(2)
	In Freight Rate	In Freight Rate
In Opp Dir Predicted Trade Value	0.0144 (0.00740)	0.0143 (0.00760)
Ex-Time & Im-Time FE	Y	Y
Dyad FE	Y	
Product FE	Y	
Dyad-Product FE		Y
Observations	258532	258532
$R^2$	0.973	0.975
F	3.801	3.540

Robust standard errors in parentheses are clustered by route.

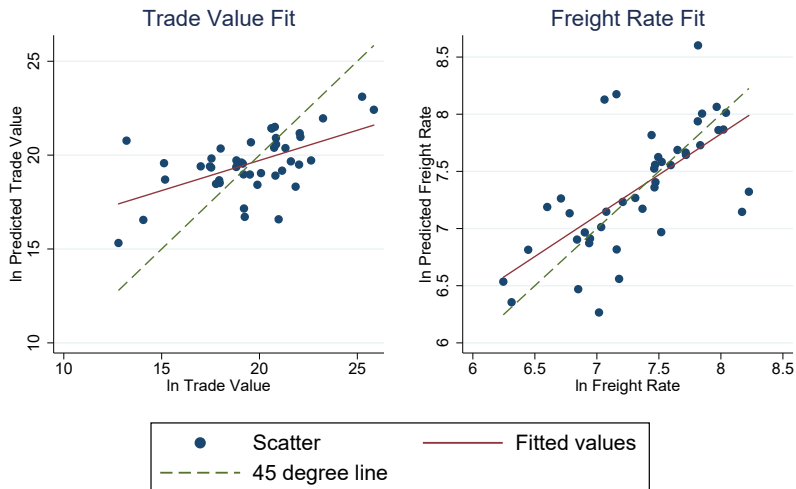
\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

Products that are typically fragmented in the production process (as identified in Fort (2016)) are removed from sample. All variables are in logs. Trade value, weight, and value per weight are aggregated to the HS2 level. The predicted trade instrument is constructed at the HS4 level with Jan 2003 data using only OECD countries.

Fixed Effects explanation: Ex-Time FE is exporter country and time fixed effects; Im-Time FE is importer country and time fixed effects.

Sources: Drewry and USA Trade Online (Monthly 2011-June 2016)

### Out of Sample Fit



22 US port-country routes. 2014 estimates used to fit 2015 data.  
Corr = 0.6 for trade value; Corr = 0.7 for freight rates

Table A.7: Containerized Trade Demand Estimates for OECD Countries with 2009 instrument

	(1)	(2)	(3)	(4)
	OLS	OLS	IV	IV
<b>Panel A: In Trade Value</b>				
In Freight Rate	-0.640*** (0.147)	-0.503*** (0.131)	-1.919* (0.715)	-1.044 (0.670)
<b>Panel B: In Trade Weight</b>				
In Freight Rate	-1.014*** (0.195)	-0.808*** (0.175)	-2.436** (0.878)	-1.302 (0.778)
<b>Panel C: In Trade Value per Weight</b>				
In Freight Rate	0.374*** (0.0688)	0.305*** (0.0675)	0.518* (0.200)	0.258 (0.185)
Ex-Time & Im-Time FE	Y	Y	Y	Y
Dyad FE	Y		Y	
Product FE	Y		Y	
Dyad-Product FE		Y		Y
Observations	118030	118030	118030	118030
First Stage F			27.12	26.43

Robust standard errors in parentheses are clustered by route. \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

Results are robust to clustering at the route and products, dyad (two-way route), as well as dyad with product levels. All variables are in logs. Trade outcome is aggregated to the HS2 level. Table A.8 presents the first stage regressions. The predicted trade instrument is constructed at the HS4 level with Jan 2009 data using only OECD countries.

Fixed Effects explanation: Ex-Time FE is exporter country and time fixed effects and Im-Time FE is importer country and time fixed effects.

Sources: Drewry and USA Trade Online (Monthly 2011-June 2016)

Table A.8: First-Stage Regressions of Containerized Trade Demand Estimates for OECD Countries with 2009 instrument (table A.7)

	(1)	(2)
	ln Freight Rate	ln Freight Rate
In Opp Dir Predicted Trade Value	0.0511*** (0.00981)	0.0485*** (0.00943)
Ex-Time & Im-Time FE	Y	Y
Dyad FE	Y	
Product FE	Y	
Dyad-Product FE		Y
Observations	118030	118030
$R^2$	0.971	0.973
F	27.12	26.43

Robust standard errors in parentheses are clustered by route.

\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

Results are robust to clustering at the route and product, dyad (two-way route), and dyad with products level. All variables are in logs. Trade value is aggregated to the HS2 level.

The predicted trade instrument is constructed at the HS4 level with Jan 2009 data using only OECD countries.

Fixed Effects explanation: Ex-Time FE is exporter country and time fixed effects; Im-Time FE is importer country and time fixed effects; Prod-Ex-T FE is product, exporter country, and time fixed effects; Prod-Im-T FE is product, importer country, and time fixed effects.

Sources: Drewry and USA Trade Online (Monthly 2011-June 2016)

Table A.9: Containerized Trade Demand Estimates for OECD Countries at the Annual Level

	(1)	(2)	(3)	(4)
	OLS	OLS	IV	IV
<b>Panel A: In Trade Value</b>				
In Freight Rate	-0.373 <sup>+</sup> (0.221)	-0.215 (0.262)	-1.683* (0.808)	-1.550 <sup>+</sup> (0.855)
<b>Panel B: In Trade Weight</b>				
In Freight Rate	-0.616* (0.273)	-0.433 (0.314)	-2.272* (0.927)	-1.982* (0.955)
<b>Panel C: In Trade Value per Weight</b>				
In Freight Rate	0.243** (0.0829)	0.218* (0.0831)	0.589** (0.174)	0.432* (0.183)
Ex-Time & Im-Time FE	Y	Y	Y	Y
Dyad FE	Y		Y	
Product FE	Y		Y	
Dyad-Product FE		Y		Y
Observations	17566	17566	17566	17566
First Stage F			68.31	55.69

Robust standard errors in parentheses are clustered by route. \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

All variables are in logs and aggregated to the annual level. Trade value, weight, and value per weight are aggregated to the HS2 level. Table A.10 presents the first stage regressions. The predicted trade instrument is constructed at the HS4 level with Jan 2003 data using only OECD countries. Second stage is run on all countries.

Fixed Effects explanation: Ex-Time FE is exporter country and time fixed effects; Im-Time FE is importer country and time fixed effects.

Sources: Drewry and USA Trade Online (Monthly 2011-June 2016)

Table A.10: First-Stage Regressions of Containerized Trade Demand  
Estimates for OECD Countries at the Annual Level (table A.9)

	(1)	(2)
	ln Freight Rate	ln Freight Rate
In Opp Dir Predicted Trade Value	0.0664*** (0.00803)	0.0647*** (0.00867)
Ex-Time & Im-Time FE	Y	Y
Dyad FE	Y	
Product FE	Y	
Dyad-Product FE		Y
Observations	17566	17566
$R^2$	0.977	0.979
F	68.31	55.69

Robust standard errors in parentheses are clustered by route.

\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

All variables are in logs and aggregated to the annual level. Trade value, weight, and value per weight are aggregated to the HS2 level. The predicted trade instrument is constructed at the HS4 level with Jan 2003 data using only OECD countries.

Fixed Effects explanation: Ex-Time FE is exporter country and time fixed effects; Im-Time FE is importer country and time fixed effects.

Sources: Drewry and USA Trade Online (Monthly 2011-June 2016)

Table A.11: Containerized Trade Demand Estimates for OECD Countries by Rauch (1999)  
Product Classification

	(1)	(2)	(3)	(4)
	OLS	OLS	IV	IV
<b>Homogeneous Products</b>				
<b>Panel 1.A: In Trade Value</b>				
In Freight Rate	-0.953*** (0.199)	-0.865*** (0.217)	-4.338*** (1.093)	-4.011** (1.419)
<b>Panel 1.B: In Trade Weight</b>				
In Freight Rate	-1.426*** (0.265)	-1.361*** (0.276)	-5.770*** (1.397)	-4.957** (1.535)
<b>Panel 1.C: In Trade Value per Weight</b>				
In Freight Rate	0.473*** (0.0915)	0.496*** (0.107)	1.432*** (0.403)	0.947* (0.445)
Observations	45889	45889	45889	45889
<b>Differentiated Products</b>				
<b>Panel 2.A: In Trade Value</b>				
In Freight Rate	-0.186 (0.158)	-0.180 (0.130)	-3.105* (1.158)	-2.689* (1.001)
<b>Panel 2.B: In Trade Weight</b>				
In Freight Rate	-0.490* (0.203)	-0.409* (0.168)	-3.943** (1.294)	-3.406** (1.067)
<b>Panel 2.C: In Trade Value per Weight</b>				
In Freight Rate	0.304*** (0.0848)	0.229** (0.0823)	0.838* (0.315)	0.716** (0.250)
Observations	63816	63816	63816	63816
Ex-Time & Im-Time FE	Y	Y	Y	Y
Dyad FE	Y		Y	
Product FE	Y		Y	
Dyad-Product FE		Y		Y

Robust standard errors in parentheses are clustered by route. \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

All variables are in logs. Trade value, weight, and value per weight are aggregated to the HS2 level. Table A.12 presents the first stage regressions. The predicted trade instrument is constructed at the HS4 level with Jan 2003 data using only OECD countries. The homogeneous goods product group is defined as both the homogeneous and reference-price goods from Rauch (1999).

Fixed Effects explanation: Ex-Time FE is exporter country and time fixed effects; Im-Time FE is importer country and time fixed effects.

Sources: Drewry and USA Trade Online (Monthly 2011-June 2016)

Table A.12: First-Stage Regressions of Containerized Trade Demand Estimates for OECD Countries by Rauch (1999) Product Classification (table A.11)

	(1)	(2)
	ln Freight Rate	ln Freight Rate
<b>Homogeneous Products</b>		
In Opp Dir Predicted Trade Value	0.0417*** (0.0112)	0.0357** (0.0108)
Observations	45889	45889
F	13.80	10.88
<b>Differentiated Products</b>		
In Opp Dir Predicted Trade Value	0.0381** (0.0119)	0.0354** (0.0113)
Observations	63816	63816
F	10.32	9.789
Ex-Time & Im-Time FE	Y	Y
Dyad FE	Y	
Product FE	Y	
Dyad-Product FE		Y

Robust standard errors in parentheses are clustered by route.

\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

All variables are in logs. Trade value, weight, and value per weight are aggregated to the HS2 level. The predicted trade instrument is constructed at the HS4 level with Jan 2003 data using only OECD countries. The homogeneous goods product group is defined as both the homogeneous and reference-price goods from Rauch (1999).

Fixed Effects explanation: Ex-Time FE is exporter country and time fixed effects; Im-Time FE is importer country and time fixed effects.

Sources: Drewry and USA Trade Online (Monthly 2011-June 2016)



## **B For Online Appendix Only: The Round Trip Effect and Search in Endogenous Transport Costs**

The round trip effect is a key feature of the transportation industry which constrains carriers, such as containerships and airplanes, to a round trip and introduces joint transportation costs which links transport supply bilaterally between locations on major routes (Pigou and Taussig (1913), Demirel, Van Ommeren and Rietveld (2010)). Wong (2018) establishes that one of the main implications from the round trip effect is that trade shocks that affect a country's trade with a partner, like preference changes or tariffs, will generate spillovers onto the country's opposite direction trade with the same partner.

This result in Wong (2018), however, relies on the assumption the quantity of goods transported between these countries are the same.<sup>39</sup> Specifically, trade shocks are restricted such that transport prices remains strictly positive and so are always able to clear the market. Since the carriers service a round trip journey, this means that its capacity is equal in both directions and therefore the quantity of traded goods transported in both directions is also equal.<sup>40</sup>

This paper investigates the robustness of the spillover result from Wong (2018) by relaxing her main assumption. I start with the same Armington trade model in Wong (2018) with a transportation industry constrained to service a round trip. The difference between this model and Wong (2018) is this: in order to export, manufacturing firms will need to successfully find a transport firm and negotiate a transport price. This operation matches the fact that there are long term contracts in container shipping which are negotiated. These contracts can provide more favorable terms to an exporter who can commit to moving a steady stream of goods over time—a larger or more productive exporter. A more productive manufacturing firm will be able to negotiate for a lower transport price and thus export at a lower cost than a less productive firm. This search

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<sup>39</sup>This assumption is relaxed in the counterfactual section in Wong (2018) such that the quantity of transport services between countries, like the number of containers, are the same. The transported quantities are then allowed to differ with a container loading factor.

<sup>40</sup>There is a second possible equilibrium outcome where there is excess capacity in one direction while the other is at capacity. However the transport price on the excess capacity direction, from that equilibrium, will be zero while the transport price on the full capacity direction will be equal to the carrier's marginal cost of servicing the round trip. Since the observed container price data in Wong (2018) is nonzero, the balanced quantity equilibrium is the focus.

process smooths the relationship between price and quantity relative to the trade shocks which renders the balanced quantity assumption unnecessary.

This paper shows that the main spillover predictions from Wong (2018) hold without the balanced trade assumption. An increase in a country's tariffs on its trading partner's good will result in an increase in the country's export transport costs to the same partner. This is because the decrease in the country's imports due to its tariff rise will result in less incoming transport firms. From the round trip effect, the number of outgoing transport firms will decrease as well. However, since the partner's demand for the country's exports have not changed, the fall in transport supply will result in a relative rise in export transport costs which decreases its equilibrium export quantity and value to the partner it was imposing protectionist policies on. On the flip side, an increase in a country's preferences for its trading partner's good will result in a decrease in the country's export transport cost to the same partner and an increase in its export quantity and value to the same. This result provides evidence for the robust relationship between the round trip effect and the spillover of shocks between a country's two-way trade with one particular trading partner via transport costs.

The first section describes the model setup and its five stages. Sections 2 to 6 highlight each stage respectively. Section 7 characterizes the equilibrium and section 8 presents the main predictions of the model. Section 9 concludes.

## **B.1 Model Setup**

The trade model is an augmented partial equilibrium Armington model with multiple countries from Hummels, Lugovskyy and Skiba (2009) with three types of agents: consumers, manufacturing firms, and transport firms.<sup>41</sup> Consumers in each country maximize utility by consuming two types of goods—a differentiated good that can be produced locally or abroad as well as a homogeneous local good. Countries are heterogeneous and each has one manufacturing firm which produces a unique manufacturing variety and prices like a monopolistically competitive firm. These firms choose production to just meet local demand or to export as well. If they export, they require a transport firm to ship their goods to the destination country. The firm will need to

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<sup>41</sup>The theory model in Wong (2018) introduces three modifications. The first is the incorporation of the round trip constraint into the transport firm's profit function. Second, countries are allowed to be heterogeneous. Third, perfectly competitive transport firms are assumed. The fourth novel modification in this paper is the inclusion of a search and bargaining process between manufacturing and transport firms.

successfully find a transportation firm and negotiate a transport price in order to export. This operation is modeled as a search and bargaining process between the exporting manufacturing firm and the transport firm.

The transport firms are homogeneous and perfectly competitive. The round trip effect applies to these firms in that they have to commit to a round trip service if they enter the market. This is due to the fact that the vessels, trucks, and airplanes utilized by transport firms are re-used and so have to return to the origin so that they can continue to provide transportation services. In the model, this translates into their joint profits in both direction being non-negative.

There are five stages in this model:

1. Entry decision of the transport firms (carriers). Since carriers commit to servicing a round trip route upon entry, they will enter the market only if their expected joint profits in both directions are non-negative.
2. Export decision of the manufacturing firms (exporters). Upon receiving their productivity draw, a manufacturing firm will choose to export or not based on their expected profits from selling the variety as well as going through the search process.
3. Export production decision of the firms. An exporter whose productivity is above the export threshold from the previous stage will produce to maximize its export profits.
4. Search and bargaining process between exporters and carriers. An exporter needs to successfully search for a carrier and bargain with them for their services in order to export. Exporters who are unsuccessful will not be able to sell their goods but will still have to pay for production costs.
5. Consumers maximize utility by consuming a mixture of locally produced and imported differentiated goods as well as a homogeneous good subject to a budget constraint.

Hummels, Lugovsky and Skiba (2009) is the basis for manufacturing firms and consumers while Miao (2006) is the basis for the search and bargaining model between exporters and carriers. This model is solved by backward induction and each stage of the model is introduced below.

## B.2 Consumer demand

I assume that the world consists of  $M$  potentially heterogeneous countries where each country produces a different variety ( $\omega$ ) of a tradeable good.<sup>42</sup> Consumers consume varieties of the tradeable good from this set of countries as well as a homogeneous numeraire good. The quasilinear utility function of a representative consumer in country  $j$  is

$$U_j = q_{j0} + \int^M a_{ij} q_{ij}(\omega)^{(\sigma-1)/\sigma} d\omega, \quad \sigma > 1 \quad (26)$$

where  $q_{j0}$  is the quantity of the numeraire good consumed by country  $j$ ,  $a_{ij}$  is  $j$ 's preference for the variety from country  $i$ ,<sup>43</sup>  $q_{ij}$  the quantity of variety consumed on route  $ij$ , while  $\sigma$  is the price elasticity of demand.<sup>44</sup> The numeraire good, interpreted as services here, is costlessly traded and its price is normalized to one.

## B.3 Transport cost determination

In order for exporters in  $i$  to export  $q_{ij}$  amount of its goods to country  $j$ , they need to engage the transport services of the carrier. This is modeled as a process of search, matching, and bargaining in a decentralized market. Once a match occurs, the exporter and carrier will bargain over the price of the transport service,  $t_{ij}$ .

The object of bargain here—transportation services—deserve some explanation. It is not one container since most exporters ship more than one container. It is also not an entire ship since an average exporter does not ship 4000 containers—the average capacity of a containership. The reality is somewhere in between. As such, this model adopts the same interpretation as Wong (2018)—the object of bargain is a shipment of goods that includes all the products that an exporter exports to one particular country. For example if there is a exporter who wants to export 5 containers worth of goods from  $i$  to  $j$ , she will search for a carrier who is going from  $i$  to  $j$ . They negotiate for the price of the 5 container shipment and the export takes place if the negotiation is successful. A carrier picks its round trip capacity to be larger of its shipments within a round trip.

Exporters are heterogeneous, monopolistically competitive, and each produces one

<sup>42</sup>There is one exporter per country and so the good variety  $\omega$  translates into the productivity draw of the exporter firm  $\varphi$ .

<sup>43</sup>Preference parameter  $a_{ij}$  can also be interpreted as the attractiveness of country  $i$ 's product to country  $j$  (Head and Mayer (2014)).

<sup>44</sup>Similar to Hummels, Lugovskyy and Skiba (2009),  $\sigma$  is the price elasticity of demand:  $\frac{\partial q_{ij}}{\partial p_{ij}} \frac{q_{ij}}{p_{ij}} = -\sigma$  (equation (26)).

variety.<sup>45</sup> Carriers are homogeneous and incur cost  $\psi_{ij}$  of transporting a shipment which is independent of quantity. Examples of this cost include the loading and unloading cost, the cost of hiring a captain and crew, as well as the capital cost of deploying a ship. There are  $M_{Ex,ij}$  number of exporters and  $M_{C,ij}$  number of carriers which are endogenously determined in equilibrium.

There are two frictions in the search process for a trader, who can be an exporter or carrier. First, there is a positive discount rate of  $r \in (0, 1]$ . Second, search incurs an explicit cost  $\rho > 0$ . Following Miao (2006), it is assumed that a trader contacts another trader according to a Poisson process with intensity  $\rho$ . A trader is a carrier with probability  $\zeta_{ij}(\tilde{\varphi}_{ij}) = \frac{M_{C,ij}}{M_{C,ij} + M_{Ex,ij}}$  where  $\tilde{\varphi}_{ij}$  is the exporter's productivity threshold for search. An exporter whose productivity is  $\tilde{\varphi}_{ij}$  will be indifferent between exporting—which necessitates searching for a carrier—and not.

At any time, an exporter with productivity  $\varphi$  meets a carrier with probability  $\rho \zeta(\tilde{\varphi}_{ij})$ . If she can negotiate and agree on a price with the carrier, she can export her goods and obtain her producer surplus in the form of export revenue minus transport cost ( $t_{ij}$ ),  $[(p_{ij}(\varphi) - t_{ij}(\varphi)) q_{ij}(\varphi)]$ .<sup>46</sup> If not, the goods expire and are not sold.<sup>47</sup> A carrier meets an exporter with probability  $\rho(1 - \zeta_{ij}(\tilde{\varphi}_{ij}))$ . If his negotiations with the exporter is successful, he sells his services for  $t_{ij}(\varphi)$  and receives a profit of  $(t_{ij}(\varphi) q_{ij}(\varphi) - \psi_{ij})$ . The carrier's revenue increases with the amount of goods he transports in one shipment. If the bargaining is unsuccessful, he gets zero profit.

When an exporter meets a carrier, they negotiate a transport price where one of the two randomly announces a take-it-or-leave-it price offer. If the offer is accepted, the trade occurs and they leave the market. If the offer is rejected, the exporter continues searching. Let  $V_{Ex,ij}(\varphi)$  be the expected payoff of an exporter with productivity  $\varphi$  and  $V_{C,ij}$  be the expected payoff of a carrier. The bargaining problem between exporter and

<sup>45</sup>Following Chaney (2008) and Melitz (2003), exporters are heterogeneous in their productivity (assume Pareto distribution  $G(\varphi) = P(\varphi^* < \varphi)$  of productivity  $\varphi$  with shape parameter  $\gamma \sim [1, +\infty)$ ).

<sup>46</sup>Note that including tariffs in the producer surplus would be straightforward. It would involve adding another term after transport cost and since tariffs are exogenous here its comparative statics would be the same as assuming exogenous transport cost. If tariffs from  $i$  to  $j$  are  $\tau_{ij}$ , the producer surplus is  $[(p_{ij}(\varphi) - t_{ij}(\varphi) - \tau_{ij}) q_{ij}(\varphi)]$ .

<sup>47</sup>The inability of exporters to sell their goods if the search is unsuccessful is a simplification. An earlier version of this model allows for unsuccessful exporters to sell their goods locally. The end result between the earlier model and the present version is qualitatively similar. The present version is chosen for simplicity.

carrier is as follows:

$$\max_{t_{ij}} \left[ (p_{ij}(\varphi) - t_{ij}(\varphi)) q_{ij}(\varphi) - V_{Ex,ij}(\varphi) \right]^\eta \left[ t_{ij}(\varphi) q_{ij}(\varphi) - \psi_{ij} - V_{C,ij} \right]^{1-\eta}$$

where  $p_{ij}$  is the per unit price of the export goods,  $t_{ij}$  is the per unit transport price,  $q_{ij}$  is the quantity of exports,  $\psi_{ij}$  is the cost to transport the goods,<sup>48</sup> and  $\eta \in (0, 1)$  is the relative bargaining power of the exporter. This bargaining problem is subject to the fact that exporters and carriers are risk-neutral and enter the market if their expected payoff is positive and only if their expected payoff is non-negative,  $(p_{ij}(\varphi) - t_{ij}(\varphi)) q_{ij}(\varphi) \geq V_{Ex,ij}(\varphi)$  and  $t_{ij}(\varphi) q_{ij}(\varphi) - \psi_{ij} \geq V_{C,ij}$ . As such, the transport price for one unit of good is as follows:

$$t_{ij}(\varphi) = \frac{1}{q_{ij}(\varphi)} \left[ \eta (\psi_{ij} + V_{C,ij}) + (1 - \eta) (p_{ij}(\varphi) q_{ij}(\varphi) - V_{Ex,ij}(\varphi)) \right] \quad (27)$$

where the transport price is increasing in the cost of providing transport services ( $\psi_{ij}$ ), the exporter's relative bargaining power ( $\eta$ ), as well as the expected payoff of the carriers ( $V_{C,i}$ ). It is decreasing in the relative bargaining power of the carriers ( $1 - \eta$ ) and the expected payoff of the exporters ( $V_{Ex,i}$ ). The effect of export quantity  $q_{ij}(\varphi)$  on transport price depends on the bargaining parameters, cost of shipping, and magnitudes of the value functions.<sup>49</sup>

The value function of the exporter's search process ( $V_{Ex,ij}$ ) conditional on its productivity  $\varphi$  being above the search threshold  $\varphi \geq \tilde{\varphi}_{ij}$ , is:

$$rV_{Ex,i}(\varphi, \tilde{\varphi}_{ij}) = \rho \zeta_{ij}(\tilde{\varphi}_{ij}) \max \left\{ \left[ (p_{ij}(\varphi) - t_{ij}(\varphi)) q_{ij}(\varphi) - V_{Ex,ij}(\varphi) \right], 0 \right\} \quad (28)$$

where the probability of meeting a carrier is  $\rho \zeta_{ij}(\tilde{\varphi}_{ij})$  and the exporter's total profit from exporting is the difference between its export revenue and transport cost,  $(p_{ij}(\varphi) - t_{ij}(\varphi)) q_{ij}(\varphi)$ .<sup>50</sup>

The value function of the carrier  $V_{C,ij}$  is as follows:

$$rV_{C,ij}(\tilde{\varphi}_{ij}) = \rho (1 - \zeta_{ij}(\tilde{\varphi}_{ij})) E_F \left[ \max \left\{ \left[ t_{ij}(\varphi) q_{ij}(\varphi) - \psi_{ij} - V_{C,i} \right], 0 \right\} \right] \quad (29)$$

where  $\rho (1 - \zeta_{ij}(\tilde{\varphi}_{ij}))$  is the probability of a carrier meeting an exporter, and the carrier's expected profits is the difference between its revenue and its cost from providing transport.

Incorporating the bargaining outcome of the transport price in (27), the exporter

<sup>48</sup>As mentioned earlier, this cost is independent of quantity. It is possible to include a marginal cost of transporting the goods that also depends on quantity and the results would not change.

<sup>49</sup> $\frac{\partial t_{ij}(\varphi)}{\partial q_{ij}(\varphi)} = \frac{(1-\eta)V_{Ex,ij}(\varphi) - \eta(\psi_{ij} + V_{C,ij})}{q_{ij}(\varphi)^2}$ .

<sup>50</sup>Since exporters have already produced their goods before searching for a carrier, their search value function does not include production costs of their goods.

value function from (28) as well as the the carrier's value function from (29) can be re-written as

$$\begin{aligned} rV_{Ex,ij}(\varphi, \tilde{\varphi}_{ij}) &= \rho \zeta_{ij}(\tilde{\varphi}_{ij}) \eta \max \{ [p_{ij}(\varphi)q_{ij}(\varphi) - V_{Ex,ij}(\varphi) - \psi_{ij} - V_{C,ij}], 0 \} \\ rV_{C,ij}(\tilde{\varphi}_{ij}) &= \rho(1 - \zeta_{ij}(\tilde{\varphi}_{ij}))(1 - \eta)E_G [\max \{ [p_{ij}(\varphi)q_{ij}(\varphi) - V_{Ex,ij}(\varphi) - \psi_{ij} - V_{C,ij}], 0 \}] \end{aligned} \quad (30)$$

The exporter's value function  $V_{Ex,i}(\varphi, \tilde{\varphi}_{ij})$  is increasing in its productivity  $\varphi$  since more productive exporters have a higher willingness to pay for transport services. So exporters from  $i$  to  $j$ , there exists a cutoff value  $\tilde{\varphi}_{ij} > 0$  such that only exporters with  $\varphi \geq \tilde{\varphi}_{ij}$  have non-negative gains from trade. This cutoff value is the search threshold  $\tilde{\varphi}_{ij}$ :

$$p(\tilde{\varphi}_{ij})q(\tilde{\varphi}_{ij}) - V_{Ex,ij}(\tilde{\varphi}_{ij}, \tilde{\varphi}_{ij}) - \psi_{ij} - V_{C,ij}(\tilde{\varphi}_{ij}) = 0 \quad (31)$$

An exporter with productivity  $\tilde{\varphi}_{ij}$  will be indifferent between searching or not,  $V_{Ex,ij}(\tilde{\varphi}_{ij}, \tilde{\varphi}_{ij}) = 0$ . Any exporter whose productivity is lower than the search threshold  $\varphi < \tilde{\varphi}_{ij}$  will have negative gains from searching and exporting  $V_{Ex,ij}(\varphi, \tilde{\varphi}_{ij}) < 0$ . As such, only exporters with productivity above this threshold  $\varphi \geq \tilde{\varphi}_{ij}$  will enter the search.

Since the exporter's expected payoff at the threshold is zero ( $V_{Ex,ij}(\tilde{\varphi}_{ij}, \tilde{\varphi}_{ij}) = 0$ ), equation (31) also determines the carrier's value function for one direction of a round trip from  $i$  to  $j$ :

$$V_{C,ij}(\tilde{\varphi}_{ij}) = p(\tilde{\varphi}_{ij})q(\tilde{\varphi}_{ij}) - \psi_{ij} \equiv R_{ij} \quad (32)$$

A carrier's expected payoff is equal to the marginal participating exporter's export revenue minus the cost of providing transport. When a carrier meets the marginal participating exporter, the transport price is a function of the exporter's productivity which in this case is the search threshold ( $t_{ij}(\tilde{\varphi}_{ij})$ ). Since all the carriers are homogeneous,  $R_{ij}$  is the common reservation value for all carriers.

In steady state, the number of exporters  $M_{Ex,ij}$  should equal the number of firms whose productivity is above the search threshold. Since exporters and carriers exit the market in pairs once a trade is made, the condition below holds:<sup>51</sup>

$$\zeta_{ij}(\tilde{\varphi}_{ij})\rho M_{Ex,ij} = \rho(1 - \zeta_{ij}(\tilde{\varphi}_{ij}))M_{C,ij} \quad (33)$$

<sup>51</sup>This follows from the matching probability which is the probability of meeting a carrier:  $\zeta_{ij}(\tilde{\varphi}_{ij}) = \frac{M_{C,ij}}{M_{C,ij} + M_{Ex,ij}}$ .

## B.4 Export production

In Chaney (2008) and Melitz (2003), there are two trade barriers from the perspective of an exporter: (1) a fixed cost to export defined in terms of the numeraire, and (2) a variable transport cost, or transport price as introduced in the previous section,  $t_{ij}(\varphi)$  that exporters in country  $i$  with productivity  $\varphi$  have to pay to ship their goods to destination  $j$ . In this model, transport cost is modeled as the only trade barrier.<sup>52</sup> Each exporter draws a random unit of productivity  $\varphi$ . This draw determines their willingness to pay for transport services and hence the transport price  $t_{ij}(\varphi)$ . In addition, an exporter has to search for its carrier in order to export. From the previous section, the probability of meeting a carrier is  $\rho \zeta_{ij}(\tilde{\varphi}_{ij})$  which is a function of the share of carriers in  $i$ ,  $\zeta_{ij}(\tilde{\varphi}_{ij}) = \frac{M_{C,ij}}{M_{C,ij} + M_{Ex,ij}}$ .

An exporter with productivity  $\varphi$  chooses its export price to maximize domestic and export profits. An exporter who is productive enough to export will also produce for domestic consumption. However, it can only export if its goods can be transported abroad by a carrier. Otherwise, the exporter will not be able to export. In both cases it will still have to pay for production costs since the production decision has already been made. It is assumed that there are no domestic transport costs ( $t_{ii} = 0$ ). The export profit maximization problem for an exporter with productivity  $\varphi$  in country  $i$  selling to country  $j$  is as follows:

$$\max_{p_{ij}(\varphi)} \pi_{ij}(\varphi) = \underbrace{V_{Ex,ij}(\varphi, \tilde{\varphi}_{ij})}_{\text{Surplus from exporting if search is successful}} - \underbrace{c_{ij}(\varphi)q_{ij}(\varphi)}_{\text{Production cost regardless of search outcome}} \quad (34)$$

where it is made up of two terms. The first term is the surplus from exporting if the exporter successfully finds a carrier. The second term is the marginal cost of production that the exporter has to pay in order to produce  $q_{ij}(\varphi)$  units of its good. The marginal cost term is made up of the price of the sole input, labor (wages  $w_i$ ), and the exporter's productivity:

$$c_{ij}(\varphi) \equiv \frac{w_i}{\varphi} \quad (35)$$

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<sup>52</sup>The endogenous transport cost generates the fixed cost to export since it has a fixed cost to provide transport  $\psi_{ij}$ .



## B.5 Exporter entry decision

The entry condition in equation (31) determines the search threshold  $\tilde{\varphi}_{ij}$ , where exporters are indifferent between searching or not. Here exporters with productivity  $\bar{\varphi}_{ij}$  will earn zero profit from exporting and so are indifferent between exporting or not:

$$\pi(\bar{\varphi}_{ij}) = 0 \rightarrow V_{Ex,ij}(\bar{\varphi}_{ij}, \tilde{\varphi}_{ij}) = c_{ij}(\bar{\varphi}_{ij})q_{ij}(\bar{\varphi}_{ij}) = \frac{w_i}{\bar{\varphi}_{ij}}q_{ij}(\bar{\varphi}_{ij}) \quad (36)$$

In equilibrium, the search threshold and the exporting threshold should be the same  $\bar{\varphi}_{ij} = \tilde{\varphi}_{ij}$ .

## B.6 Carrier entry decision

In order for the carriers to enter the market, their expected profits from their round trip service has to be non-negative. This means that for any round trip between  $i$  and  $j$ ,  $V_{C,ij}$  and  $V_{C,ji}$  has to be non-negative:

$$V_{C,ij}(\tilde{\varphi}_{ij}) + V_{C,ji}(\tilde{\varphi}_{ij}) \geq 0 \quad (37)$$

This means that a carrier could still serve a round trip journey when one direction generates negative profits if the other direction makes up for the loss. Since carriers who enter the market commit to a round trip route, there has to be the same number of carriers going from  $i$  to  $j$  and back

$$M_{C,ij} = M_{C,ji} \quad (38)$$

## B.7 Solving for the Equilibrium

For the tradeable good, the solution to the consumer's problem in (26) takes the CES form:

$$q_{ij} = \left[ \frac{\sigma}{\sigma - 1} \frac{1}{a_{ij}} p_{ij} \right]^{-\sigma} \quad (39)$$

An increase in  $j$ 's preference for  $i$ 's good ( $a_{ij}$ ) will increase its demanded quantity while an increase in the export price ( $p_{ij}$ ) will decrease the quantity.

The exporter's value function in (30), conditional on its productivity being above the search threshold  $\tilde{\varphi}_{ij}$ , can be rewritten as:

$$V_{B,i}(\varphi, \tilde{\varphi}_{ij}) = \frac{\rho \eta \zeta_{ij}(\tilde{\varphi}_{ij})}{r + \rho \eta \zeta_{ij}(\tilde{\varphi}_{ij})} [p_{ij}(\varphi)q_{ij}(\varphi) - \psi_{ij} - R_{ij}], \text{ for } \varphi \geq \tilde{\varphi}_{ij} \quad (40)$$

By inserting the rewritten exporter's value function from (40) into the transport price

bargaining outcome in (27), the following can be shown:

$$t_{ij}(\varphi) = \frac{1}{q_{ij}(\varphi)} \left[ \psi_{ij} + R_{ij} + \frac{r(1-\eta)}{r + \rho \zeta_{ij}(\tilde{\varphi}_{ij})\eta} [(p_{ij}(\varphi)q_{ij}(\varphi) - \psi_{ij} - R_{ij})] \right], \text{ for } \varphi \geq \tilde{\varphi}_{ij} \quad (41)$$

Holding the search cost  $\rho$  and the productivity threshold  $\tilde{\varphi}_{ij}$  constant, the transport price is decreasing in the match probability ( $\frac{\partial t_{ij}}{\partial \zeta_{ij}} \leq 0$ ) and in the cost for the carrier to provide transport ( $\frac{\partial t_{ij}}{\partial \psi_{ij}} \leq 0$ ). Since exporter revenue  $p(\varphi)q(\varphi)$  is increasing in productivity  $\varphi$  ( $\frac{\partial p(\varphi)q(\varphi)}{\partial \varphi} \geq 0$ ) and total transport price is increasing in exporter revenue ( $\frac{\partial t_{ij}(\varphi)q(\varphi)}{\partial p(\varphi)q(\varphi)} \geq 0$ ), total transport cost is increasing in productivity—more productive exporters pay higher total transport costs. However, the per unit transport prices these exporters pay are decreasing in the volume of goods their export. As such, per unit transport price is decreasing in productivity—all else equal, more productive exporters pay less for transport.

The equilibrium matching probability  $\zeta_{ij}$  is solved for by substituting the new exporter value function in (40) into the carrier's value function in (30)

$$\zeta_{ij}(\tilde{\varphi}_{ij}) = \frac{\rho(1-\eta)E_G [p_{ij}(\varphi)q_{ij}(\varphi) - \psi_{ij} - R_{ij}] - r(R_{ij})}{\rho [\eta R_{ij} + (1-\eta)E_G [p_{ij}(\varphi)q_{ij}(\varphi) - \psi_{ij} - R_{ij}]]} \quad (42)$$

where  $E_G [p_{ij}(\varphi)q_{ij}(\varphi) - \psi_{ij} - R_{ij}] = \int_{\tilde{\varphi}_{ij}}^{\infty} p_{ij}(\varphi)q_{ij}(\varphi) - \psi_{ij} - R_{ij} dG(\varphi)$ . Given equilibrium matching probability  $\zeta_{ij} = \frac{M_{C,ij}}{M_{C,ij} + M_{Ex,ij}}$  and the carrier's non-negative round trip profits in (37), the number of carriers will match the number of exporters who choose to enter from condition (31).

The optimal export profit-maximizing price  $p_{ij}(\varphi)$  from (34) is a constant mark-up over unit cost of production plus a transport cost of the iceberg form  $T_{ij}$ :

$$\begin{aligned} p_{ij}(\varphi) &= \frac{\sigma}{\sigma-1} \frac{w_i}{\varphi} \frac{r + \rho \zeta_{ij}(\tilde{\varphi}_{ij})\eta}{\rho \zeta_{ij}(\tilde{\varphi}_{ij})\eta (r + \rho \zeta_{ij}(\tilde{\varphi}_{ij}))} \\ &\equiv \frac{\sigma}{\sigma-1} \frac{w_i}{\varphi} T_{ij}(\tilde{\varphi}_{ij}) \end{aligned} \quad (43)$$

Since  $\rho$ ,  $\zeta_{ij}$ ,  $\eta$ , and  $r$  are all fractions respectively,  $T_{ij}(\tilde{\varphi}_{ij}) > 1$ .<sup>53</sup>

The export price for goods from country  $i$  to  $j$  is increasing in local wages  $w_i$ , decreasing in the exporter's productivity  $\varphi$ , and increasing in the cost of transport  $T_{ij}$ . The cost of shipping increases with the decrease in the probability of successful search  $\rho \zeta_{ij}$ . Intuitively, the exporter's bargaining power  $\eta$  relative to the carrier decreases

<sup>53</sup> Since  $\eta < 1$ ,  $r > \eta r \rightarrow r + \rho \zeta_{ij}\eta > \eta r + \rho \zeta_{ij}\eta \rightarrow \frac{r + \rho \zeta_{ij}\eta}{\eta \rho \zeta_{ij}\eta} > 1$ .

$\eta \rightarrow 0$ , the transport price increases  $T_{ij} \rightarrow \infty$  as does the export price  $p_{ij} \rightarrow \infty$ .

The export profits of an exporter with productivity  $\varphi > \bar{\varphi}_{ij}$  from  $i$  to  $j$  is

$$\begin{aligned}\pi_{ij}(\varphi) &= \frac{\rho \zeta_{ij}(\bar{\varphi}_{ij}) \eta (r + \rho \zeta_{ij}(\bar{\varphi}_{ij}))}{r + \rho \zeta_{ij}(\bar{\varphi}_{ij}) \eta} [p_{ij}(\varphi) q_{ij}(\varphi) - R_{ij} - \psi_{ij}] - \frac{w_i}{\varphi} q_{ij}(\varphi) \\ &= \frac{1}{T_{ij}(\bar{\varphi}_{ij})} [p_{ij}(\varphi) q_{ij}(\varphi) - R_{ij} - \psi_{ij}] - \frac{w_i}{\varphi} q_{ij}(\varphi)\end{aligned}\quad (44)$$

Here a decrease in the transport price ( $T_{ij}$ ), wages ( $w_i$ ), carrier's reservation value ( $R_{ij}$ ), and the cost of providing transport services ( $\psi_{ij}$ ) will increase exporter profits. An increase in the export revenue ( $p_{ij}(\varphi) q_{ij}(\varphi)$ ) will also increase profits.

In equilibrium, an exporter's search threshold is equal to its export threshold:  $\bar{\varphi}_{ij} = \tilde{\varphi}_{ij}$ . Hence the export productivity threshold of the exporters ( $\bar{\varphi}_{ij}$ ) can be pinned down by equating their value function from search (equation (40)) to the cost of production that they pay for regardless of the search outcome. This means that the exporter earns zero profit in equation (34):<sup>54</sup>

$$\begin{aligned}\pi_{ij}(\bar{\varphi}_{ij}) = 0 &\rightarrow V_{Ex,ij}(\bar{\varphi}_{ij}, \bar{\varphi}_{ij} = \tilde{\varphi}_{ij}) = c_{ij}(\bar{\varphi}_{ij}) q_{ij}(\bar{\varphi}_{ij}) \\ \bar{\varphi}_{ij} &= \lambda_1 \left[ \frac{R_{ij} + \psi_{ij}}{a_{ij}^\sigma} \right]^{\frac{1}{\sigma-1}} w_i T_{ij}(\bar{\varphi}_{ij})\end{aligned}\quad (45)$$

Note that this export threshold is not solved in its entirety yet since the transport cost still takes the threshold as a function due to matching probability  $\zeta_{ij}(\bar{\varphi}_{ij})$ . Any manufacturing firms who draw a productivity lower than this threshold will choose to only produce domestically. All else equal, an increase in the reservation value of the carrier ( $R_{ij}$ ), the cost of providing transport ( $\psi_{ij}$ ), the cost of production ( $w_i$ ), and the transport price ( $T_{ij}(\bar{\varphi}_{ij})$ ) raises the export threshold which lowers the number of exporters. An increase in  $j$ 's preference for  $i$ 's product ( $a_{ij}$ ) will decrease the export threshold which increases the number of exporters.

Between two countries  $k$  and  $l$ , the equilibrium in this model can be described by the following (for  $k, l = i, j$  and  $k \neq l$ ): the utility-maximizing quantity of goods traded back and forth ( $q_{kl}$ ), value functions of exporters and carriers ( $V_{Ex,kl}$  and  $V_{C,kl}$ ), negotiated transport prices ( $t_{kl}(\varphi)$ ), profit-maximizing prices of goods traded back and forth ( $p_{kl}(\varphi)$ ), marginal exporters ( $\bar{\varphi}_{kl}$ ), and the stock of exporters and carriers ( $M_{Ex,kl}$  and  $M_{C,kl}$ ) such that

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<sup>54</sup>Constant  $\lambda_1 \equiv \left[ \frac{\sigma}{\sigma-1}^{-2\sigma} \frac{1}{\sigma-1} \right]^{\frac{1}{\sigma-1}}$

- (i) Quantity  $q_{kl}$  satisfies the consumer utility function in (26),
- (ii) Value functions  $V_{Ex,kl}$  and  $V_{C,kl}$  satisfy (30),
- (iii) Transport price  $t_{kl}(\varphi)$  satisfies the bargaining outcome in (27),
- (iv) Price of traded goods  $p_{kl}(\varphi)$  satisfies the exporter's profit function in (34),
- (v) The productivity of the marginal exporters  $\bar{\varphi}_{kl}$  is given by (45),
- (vi) The stock of carriers between  $k$  and  $l$  are the same ( $M_{C,kl} = M_{C,lk}$  from (38)), and
- (vii) The flow of carriers and exporters satisfies the market clearing condition in (33)

Aggregate trade flows from  $i$  to  $j$  is a share of the total expenditure on goods in country  $j$ , which is as follows:<sup>55</sup>

$$\begin{aligned}
X_{ij}(\bar{\varphi}_{ij}) &= \int_{\bar{\varphi}_{ij}}^{\infty} p_{ij}(\varphi) q_{ij}(\varphi) dG(\varphi) \\
&= \lambda a_{ij}^{\frac{\sigma\gamma}{\sigma-1}} (R_{ij} + \psi_{ij})^{1-\frac{\gamma}{\sigma-1}} (w_i T_{ij}(\bar{\varphi}_{ij}))^{-\gamma}
\end{aligned} \tag{46}$$

where all else equal, an increase in  $j$ 's preference for  $i$  ( $a_{ij}$ ) will increase aggregate trade flows. On the other hand, increasing the wages ( $w_i$ ), transport cost ( $T_{ij}$ ), and the cost of providing transport ( $\psi_{ij}$ ) will decrease aggregate flows.

## B.8 Comparative Statics

One of the main theoretical results in Proposition 1 in Wong (2018) is that the round trip effect generates spillovers of trade shocks on the origin country's imports from its trading partner onto the origin country's exports to the same partner. The same applies for trade shocks on the origin country's exports to its trading partner. These results are based on the assumption that the trade shocks are restricted such that transport prices in both directions can clear the market resulting in the same quantity of traded goods between countries. The model in this paper emphasizes the robustness of the results in Wong (2018) by providing the same spillover outcome without relying on the same assumption. This shows that the balanced quantity assumption is not crucial for the round trip effect to generate spillovers between a country's two-way trade with a partner.

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<sup>55</sup>Constant  $\lambda \equiv \frac{\sigma}{\sigma-1} \left(1 + \frac{2\sigma\gamma}{1-\sigma}\right) \frac{1}{\sigma-1} \frac{\gamma}{\sigma-1} \frac{\gamma}{\gamma-(\sigma-1)}$ .

Specifically, Lemma 1 in Wong (2018) shows that an increase in the origin country's tariffs on its trading partner decreases both its imports from and exports to the same partner. The inverse applies for an increase in its preferences for its trading partner (Lemma 2, (Wong, 2018)). Similarly, this model shows that an increase in the origin country's tariff will decrease its exports to the same partner. Inversely, an increase in its preference for goods from its partner will also increase its exports to the same partner.<sup>56</sup>

I first focus on country  $j$ 's preference for  $j$ ,  $a_{ij}$ . When country  $j$ 's preference for goods from country  $i$  increases, it is intuitive that  $j$ 's import quantity  $q_{ij}$  should increase (equation (39)). Since this also increases the revenue from exporting to country  $j$  which increases aggregate trade value  $X_{ij}$  (equation (46)), the number of exporters from  $i$  to  $j$  will also increase (lowering the export threshold  $\bar{\varphi}_{ij}$ ). This increases the demand for transport services from  $i$  to  $j$  which increases the number of carriers along the same route. Due to the round trip effect, carriers who go from  $i$  to  $j$  have to return (equation (38)). As such, while trade conditions from  $j$  to  $i$  remain unchanged (including  $i$ 's preferences for goods from  $j$   $a_{ji}$ ), there are now more carriers available to bring goods from  $j$  to  $i$ . From (33), this increases the matching probability between exporters and carriers from  $j$  to  $i$ :  $\frac{\partial \zeta_{ji}}{M_{C,ji}} > 0$ .<sup>57</sup> As a result, the transport price from  $j$  to  $i$  decreases ( $\frac{\partial T_{ji}}{\zeta_{ji}} < 0$ , equation (43)).<sup>58</sup> In turn, the export quantity and value from  $j$  to  $i$  increases while the export price falls.<sup>59</sup> The following lemma can be shown:<sup>60</sup>

**Lemma 3.** *When transport cost is determined on a round trip basis and through a search and bargaining process, an increase in origin country  $j$ 's preference for its trading partner  $i$ 's goods will affect both the origin country's imports and exports to its partner. On the export side, the home country's export transport cost and export price to its partner falls while its export quantity and value increases.*

$$\frac{\partial T_{ji}}{\partial a_{ij}} < 0, \quad \frac{\partial p_{ji}}{\partial a_{ij}} < 0, \quad \frac{\partial q_{ji}}{\partial a_{ij}} > 0 \quad \text{and} \quad \frac{\partial X_{ji}}{\partial a_{ij}} > 0$$

<sup>56</sup>The comparative statics for the mitigating effects on the imports side is not shown here for two reasons. First, the spillover results are novel and thus are the focus here. Second, this model does not yield a close-formed solution and so the mitigating effects would have to be shown analytically.

<sup>57</sup> $\frac{\partial \zeta_{ji}}{M_{C,ji}} = \frac{1}{M_{Ex,ji}} > 0$

<sup>58</sup> $\frac{\partial T_{ji}}{\zeta_{ji}} = -\frac{\rho^2 \zeta_{ji}^2 \eta + (r^2 + 2\rho \zeta_{ji})}{\zeta_{ji}(r + \rho \zeta_{ji})} < 0$

<sup>59</sup> $\frac{\partial p_{ji}}{T_{ji}} > 0$ ,  $\frac{\partial q_{ji}}{T_{ji}} < 0$ , and  $\frac{\partial X_{ji}}{T_{ji}} < 0$ .

<sup>60</sup>See appendix for proof.

In order to establish these results for tariffs, I first incorporate tariffs into this model. Tariffs are paid by the exporters and so they are incorporated into their profit functions in (34) as such:

$$\max_{p_{ij}(\varphi)} \pi_{ij}(\varphi) = \rho \zeta_{ij}(\varphi, \bar{\varphi}_{ij}) (p_{ij}(\varphi) - t_{ij}(\varphi)) q_{ij}(\varphi) - \tau_{ij} c_{ij}(\varphi) q_{ij}(\varphi) \quad (47)$$

where the first two terms are the surplus from being able to export if the exporter successfully finds a carrier. The second term is the marginal cost of production that the exporter has to pay in order to produce  $q_{ij}(\varphi)$  units of its good which includes the tariff on these goods  $\tau_{ij} > 1$ .<sup>61</sup> The marginal cost term is made up of the price of the sole input, labor ( $w_i$ ), and the exporter's productivity. The equilibrium for this model with tariffs is very similar to the equilibrium defined previously where tariffs enter the same way as wages  $w_i$ .

When country  $j$  increases its tariffs on goods from country  $i$ , it is again intuitive that its import price  $p_{ij}$  should increase which will lead to a fall in quantity  $q_{ij}$  (equation (39)).<sup>62</sup> Since this then decreases the revenue from exporting to country  $j$  ( $X_{ij}$ , equation (46)), the number of exporters will also fall which increases the export threshold  $\bar{\varphi}_{ij}$ . This decreases the demand for transport services from  $i$  to  $j$  which decreases the number of carriers along the same route. Due to the round trip effect, there are now less carriers available to bring goods from  $j$  to  $i$  all else equal (equation (38)). From (33), this decreases the matching probability between exporters and carriers from  $j$  to  $i$ :  $\frac{\partial \zeta_{ji}}{\partial \bar{\varphi}_{ij}} > 0$ . As a result, the transport price from  $j$  to  $i$  increases ( $\frac{\partial T_{ji}}{\partial \zeta_{ji}} < 0$ , equation (43)). The export quantity and value from  $j$  to  $i$  falls while price increases. The following lemma can be shown:<sup>63</sup>

**Lemma 4.** *When transport cost is determined on a round trip basis and through a search and bargaining process, an increase in the origin country  $j$ 's import tariffs on its trading partner  $i$ 's goods will affect both the origin country's imports and exports to its partner. On the export side, the origin country's export freight rate and price to its*

<sup>61</sup>This method of modeling is chosen for simplicity. Another way to model tariffs here is for the firms to only pay for it if it successfully exports. This alternative method would not change the results but would complicate the solution.

<sup>62</sup>Since  $p_{ij}(\varphi) = \frac{\sigma}{\sigma-1} \frac{w_i \tau_{ij}}{\varphi} \frac{r + \rho \zeta_{ij}(\bar{\varphi}_{ij}) \eta}{\rho \zeta_{ij}(\bar{\varphi}_{ij}) \eta (r + \rho \zeta_{ij}(\bar{\varphi}_{ij}))} \equiv \frac{\sigma}{\sigma-1} \frac{w_i \tau_{ij}}{\varphi} T_{ij}(\bar{\varphi}_{ij})$ ,  $\frac{\partial p_{ij}}{\partial \tau_{ij}} < 0$ .

<sup>63</sup>See appendix for proof.

partner will increase while its export quantity and value decreases.

$$\frac{\partial T_{ji}}{\partial \tau_{ij}} > 0, \frac{\partial p_{ji}}{\partial \tau_{ij}} > 0, \frac{\partial q_{ji}}{\partial \tau_{ij}} < 0 \text{ and } \frac{\partial X_{ji}}{\partial \tau_{ij}} < 0$$

From the results from these two lemmas, the following proposition can be established:

**Proposition 2.** *A model with the round trip effect predicts a spillover effect of trade shocks on the origin country's imports from its trading partner onto the origin country's exports to the same partner. The same applies for trade shocks on the origin country's exports to its trading partner. This result is robust under a balanced trade quantity assumption as well as a search and bargaining process between exporter and carrier without the balanced assumption. With the search and bargaining model, the traded quantities between countries are no longer constrained to be the same.*

*An increase in the origin country's tariffs on its trading partner decreases its exports to the same partner. The same applies inversely for a positive preference shock.*

## B.9 Conclusion

The cost of transporting goods between countries is determined in equilibrium by the interaction between the countries' supply and demand for transport. Additionally, carriers are re-used and therefore have to return to the origin in order to continue providing transport services. This feature of the transportation industry constrains carriers to a round trip and introduces joint transportation costs linking transport supply bilaterally between locations on major routes.

One of the main results from the round trip effect in Wong (2018) is that trade shocks that affect a country's trade with a partner will generate spillovers onto the country's opposite direction trade with the same partner. However, this result is based on the assumption the traded quantity between these countries are balanced. This paper investigates the robustness of the spillover result in Wong (2018) by relaxing her main assumption. Instead, this paper matches an industry observation that there are long term contracts in container shipping which are negotiated. As such, manufacturing firms need to successfully find a transport firm and negotiate a transport price in order to export. With this search operation, the balanced trade quantity assumption is no longer necessary.

This paper shows that the main spillover predictions from Wong (2018) holds without the balanced quantity assumption. An increase in a country's tariffs on imports from its trading partner will result in an increase in its export transport costs to the same partner. In turn, this protectionist policy also decreases in the country's export quantity and value to its trading partner. This is due to the fact that a decrease in the protectionist country's imports will decrease the number of carriers bringing its imports. The round trip effect will translate the fall in number of incoming carriers into a fall in outgoing carriers as well. Since the protectionist countries' exports to its partner has not changed and there is now less transport services supply, its export transport cost will increase. An increase in the country's preferences for its imports from its trading partner, on the other hand, will yield the opposite result: a decrease in its export transport cost to the same partner and an increase in its export quantity and value. These results provide evidence for the robust relationship between the round trip effect and the spillover of shocks between a country's two-way trade with one particular trading partner via transport costs.



## B.10 Appendix

**Proof of Lemma 3** When country  $j$ 's preference for goods from country  $i$  ( $a_{ij}$ ) increases, it is intuitive that  $j$ 's import quantity  $q_{ij}$  should also increase (equation (39)). Since in turn increases the export revenue from country  $i$  to  $j$  which increases the route's aggregate trade value  $X_{ij}$  (equation (46)). The number of exporters from  $i$  to  $j$  will also increase from the fall in export threshold  $\bar{\varphi}_{ij}$ .

Since there are more goods being shipped from  $i$  to  $j$ , the demand for transport services from  $i$  to  $j$  also goes up which increases the number of carriers along the same route. Due to the round trip effect, carriers who go from  $i$  to  $j$  have to return (equation (38)). As such, while trade conditions from  $j$  to  $i$  remain unchanged (including  $i$ 's preferences for goods from  $j$   $a_{ji}$ ), there are now more carriers available to bring goods from  $j$  to  $i$ .

From (33), the matching probability between exporters and carriers from  $j$  to  $i$  now increases:

$$\frac{\partial \zeta_{ji}}{M_{C,ji}} = \frac{1}{M_{Ex,ji}} > 0 \quad (48)$$

Since there are more carriers, the match probability between carriers and exporters from  $j$  to  $i$  is now higher.

From the higher matching probability, the transport price from  $j$  to  $i$  decreases:

$$\frac{\partial T_{ji}}{\zeta_{ji}} = -\frac{\rho^2 \zeta_{ji}^2 \eta + (r^2 + 2\rho \zeta_{ji})}{\zeta_{ji} (r + \rho \zeta_{ji})} < 0 \quad (49)$$

This is due to the fact that an exporter now has a relatively better chance of finding a carrier to match with and also more outside options during its bargaining process.

In turn, cheaper transport price means that it's now cheaper to export. As such, the export quantity and value from  $j$  to  $i$  increases while the export price falls.

**Proof of Lemma 4** When country  $j$  increases its tariffs on goods from country  $i$  ( $\tau_{ij}$ ), it is intuitive that its import price  $p_{ij}$  should increase which will lead to a fall in quantity  $q_{ij}$  (equation (39)). Since an export price increase will decrease the overall export revenue from country  $i$  to  $j$  ( $X_{ij}$ , equation (46)), the number of exporters will also fall. Similarly, this can be described as an increase in the export threshold  $\bar{\varphi}_{ij}$ .

Since the amount of goods being shipped from  $i$  to  $j$  has decreased, the demand for transport services from  $i$  to  $j$  decreases as well which lowers the number of carriers along the same route. Due to the round trip effect, there are now less carriers available

to bring goods from  $j$  to  $i$  all else equal (equation (38)).

From (33), this decreases the matching probability between exporters and carriers from  $j$  to  $i$ :

$$\frac{\partial \zeta_{ji}}{M_{C,ji}} = \frac{1}{M_{Ex,ji}} > 0 \quad (50)$$

With less carriers, there is a lower probability of matching between exporters and carriers.

As a result, the transport price from  $j$  to  $i$  increases since exporters now have less outside options in the form of other carriers as well as less chances of meeting a carrier:

$$\frac{\partial T_{ji}}{\zeta_{ji}} = -\frac{\rho^2 \zeta_{ji}^2 \eta + (r^2 + 2\rho \zeta_{ji})}{\zeta_{ji} (r + \rho \zeta_{ji})} < 0 \quad (51)$$

All this result in the export quantity and value from  $j$  to  $i$  falling while the export price increases.