The Round Trip Effect: Endogenous Transport Costs and International Trade

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Abstract

Containerships travel between a fixed set of origins and destinations in round trips, inducing a negative correlation in their freight rates. I study the implications of this round trip effect on international trade and trade policy. I identify this effect and develop an instrument using this effect to estimate the impact of transport costs on trade. I simulate counterfactual import tariff increases in a quantitative model and quantify the importance of endogenizing transport costs with respect to this effect: an exogenous transport costs model predicts a trade balance improvement from protectionist policies while the round trip model finds the opposite.

Keywords: trade costs, transport costs, transportation, trade policy, container shipping

JEL Classification: F14, F13, R40, R41

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"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."

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

Cargo ships and containers typically go back and forth between a fixed set of origins and destinations in round trips (Pigou and Taussig, 1913; Demirel, Van Ommeren and Rietveld, 2010).[1] This is an optimal strategy due to technological constraints and is well established in the transportation literature.[2] As a result, joint transportation costs are introduced which link transport supply between these locations and induce a negative correlation in their freight rates, as acknowledged by Samuelson (1954). This is not just unique to container shipping but also applies to air freight and trucking.[3]

This paper studies this feature of the transportation sector, termed the *round trip effect*, and its implications for international trade and trade policy. The round trip effect is defined as a phenomenon where exogenously-driven shocks to transport quantity from i to j in turn affect the transport price from j to i. Consider a negative exogenous shock to transport demand from i to j, for example, due to an import tariff imposed by j on i. Transport quantity on this route would decrease. Due to ships going in a round trip between i and j, transport quantity from j to i decreases as well. This increases the transport price from j to i which reduces its resultant trade. I refer to this as the spillover or backfiring consequence from the round trip effect. Additionally, this negative shock is partially mitigated by an endogenous decrease in the transport price from i to j since there is now less demand on this route. I refer to this as the mitigation consequence from the round trip effect.[4]

The first contribution in this paper is to identify the round trip effect empirically.

[1] One example is the US-China route currently serviced by Maersk, the largest containership company globally, where ships travel exclusively between Yantian and Ningbo to Long Beach and back (figure A.1).

[2] One contributing reason for this is the significant increase in containership sizes (World Shipping Council). Larger ships spend longer times at port, which has decreased their average number of port calls per route. The number of port calls per round trip loop on the Far East—North Europe trade has decreased from 5 ports of call in 1989 down to 3 in 2009 (Ducruet and Notteboom, 2012).

[3] Air cargo costs 10 times more from China to US than the return (\$3-\$3.50/kg compared to \$0.30-\$0.40/kg back; (Behrens and Picard, 2011)). US truck rentals costs two times more from Chicago to Philadelphia than the return (\$1963 at \$2.69/mile compared to \$993 at \$1.31/mile back; DAT Solutions).

[4] The round trip effect is related to the backhaul problem but not solely a consequence of it. The backhaul problem is defined as the optimal adjustment of freight routes and pricing to avoid sending empty containers on the route with the lower demand (the backhaul route). See Section 4 for further discussion.

While the existence of the round trip effect is widely accepted in the transportation literature, it has not been systematically documented due to lack of detailed data. This paper introduces a novel port-level freight rates data set with a high level of disaggregation which is able to address this issue. The main implication of the round trip effect, as predicted by my theoretical model and Samuelson (1954), is a negative correlation in freight rates between the same set of ports. To the best of my knowledge, this is the first paper to provide systematic evidence for this negative correlation. Since trade and freight rates on the same route are negatively correlated, I show that the round trip effect induces a positive correlation between freight rates and opposite-direction trade flows. To address the endogeneity between freight rates and trade flows, I construct a novel IV using the round trip insight to establish the impact of the round trip effect on freight rates. I introduce my IV below.

The second contribution in this paper uses the round trip effect to estimate a containerized trade elasticity with respect to transport price. Since containers are required to transport containerized trade, this elasticity can also be interpreted as the demand elasticity for containers. As in typical demand estimations, I require a transport supply shifter that is independent of demand determinants. The intuition for the supply shifter I utilize is as follows: due to the round trip effect, demand shocks to trade from US to China will shift transport supply in both the original (US-China) and opposite (China-US) directions. The latter transport supply shift will identify the US demand for Chinese goods if the demand shocks between the routes are uncorrelated. Since demand shifts between countries are generally not independent, I construct a shift-share instrument that approximates this transport supply shift (Bartik, 1991). 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.

The third contribution is to simulate counterfactual import tariff changes in a quantitative Armington trade model in order to evaluate the implications of this effect for trade policy. I show the broader economic importance of the round trip effect by quantifying the difference between the trade predictions from this model and a model which assumes that transport cost is exogenous. Additionally, I decompose the round trip effect into mitigation and backfiring effects. This paper simulates two trade policy counterfactuals, the impact of the US doubling its import tariffs on its trading partners and the impact of the Trump administration's Section 301 tariffs on China. Using the latter counterfactual as an example, I show that an increase in US tariffs on China would not just decrease US imports from China (the magnitude of which is mitigated by a fall in US import transport cost from China—the mitigation effect), but also decrease US exports *to* China. This export decrease is due to the overall fall in transport supply on the round trip route between US and China driven by the decrease in US imports—the spillover effect. A model assuming exogenous transport costs would over-predict the import decline by 30-35% relative to the round trip model and not predict any decrease in US exports. This results in the exogenous transport costs model predicting a trade balance improvement from protectionist policies while the round trip model finds the opposite.

This paper contributes to several strands of literature. First, it is broadly related to the literature which studies how trade costs affect trade flows between countries (Anderson and Van Wincoop, 2004; Eaton and Kortum, 2002; Head and Mayer, 2014). In particular, this paper is related to the literature on endogenous transport cost (Allen and Arkolakis, 2019; Hummels, 2007; Limao and Venables, 2001).[5] Focusing on dry bulk ships, Brancaccio, Kalouptsidi and Papageorgiou (2020) studies endogenous transport costs in the presence of search frictions between exporters and transport firms. This paper focuses on containerships which have a different technology than dry bulk ships—containerships travel in fixed round trip routes like buses while dry bulk ships do not and act more like taxis.[6] This paper contributes to this literature by investigating a new source of transport cost endogeneity—the round trip effect—and its implications for trade and trade policy. In addition to treating transport cost as an equilibrium outcome jointly determined with trade flows, transport costs are also simultaneously determined within routes as a result of the round trip effect.

Additionally, this paper is related to the literature on the round trip effect. Previous empirical studies on the round trip effect typically employ aggregated data sets, either at

[5] Behrens, Brown and Bougna (2018) and Behrens and Brown (2018) studies the impact of endogenous transport cost on geographic concentration while Asturias (2020), Francois and Wooton (2001), and Hummels, Lugovskyy and Skiba (2009) focus on market power within the transport sector.

[6] Dry bulk ships are likely to depart from their destinations without cargo and therefore have to search for their next load while containerships have fixed publicized schedules since they are able to pick up a wide variety of cargo at each stop.

the regional level (Friedt and Wilson, 2018) or within a country at the annual frequency (Tanaka and Tsubota, 2016; Jonkeren et al., 2011).[7] As such, these papers have not been able to convincingly establish the presence of the round trip effect empirically. The data set in this paper is highly disaggregated at the monthly frequency, the port-level in both directions, and includes all the largest ports globally.[8] Since containerships only take a few weeks to complete a round trip each time, it is important for my data set to have this rich level of detail in order to capture the freight rates variation between routes. This high level of disaggregation allows me contribute to this literature by providing empirical evidence for the round trip effect as well as highlighting its trade implications. I am also able to exploit the panel nature of this data set in my empirical estimations to control for confounding factors.[9]

Relative to studies on trade elasticities, this paper contributes by estimating a short-run trade elasticity, at the port level, for containerized goods. This trade elasticity also takes into account endogeneity concerns between trade and trade costs. While there are important exceptions,[10] transport costs are generally modeled as exogenous, approximated by distance empirically, and by the iceberg functional form theoretically. I develop using a novel instrument based on the institutional details of the transportation industry in order to causally identify the elasticity of containerized trade with respect to transport price. In addition, previous studies have focused on trade elasticities at the country-level and across all transport modes. My elasticity contributes to understanding how trade responds to transport costs changes at the port-level and within a mode, i.e. container shipping. Port-level trade elasticities are not often estimated due to data limitations (one recent exception being Asturias (2020)). Short-term elastiticities, especially at the monthly level, are also rarely estimated in the literature (one exception being Fajgelbaum et al. (2019)). My elasticity can shed light on how trade adjusts taking into account substitution

[7] Tanaka and Tsubota (2016) estimates the effects of trade flow imbalance on transport price ratio between Japanese prefectures. Focusing on 3 regions (North America, Asia, and Europe), Friedt and Wilson (2018) 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.

[8] This data set includes the majority of the world's leading container ports but not all operating ports.

[9] This includes addressing the orthogonality conditions for shift-share instruments (Borusyak, Hull and Jaravel, 2018).

[10] Important exceptions include Allen and Arkolakis (2019), Donaldson (2018), Asturias (2020), Hummels, Lugovskyy and Skiba (2009), and Irarrazabal, Moxnes and Opromolla (2015).

across ports and over the short run. Additionally, I contribute to studies on product-level trade elasticities by estimating a trade elasticity for containerized goods (Caliendo and Parro, 2014; Shapiro, 2015; Steinwender, 2018).

This paper also contributes to studies on the trade policy implications from the round trip effect. Ishikawa and Tarui (2018) is an applied theory paper which shows that trade policy changes in the presence of the backhaul problem can lead to a backfiring problem, increases in a country's import tariffs on its partner can lead to a decrease in its exports to the same partner. My paper empirically identifies the underlying mechanism that leads to this backfiring problem (the negative correlation in freight rates), shows that it is not just solely a consequence of routes with trade imbalance (i.e. routes that face the backhaul problem), and decomposes the round-trip effect into the mitigation effect and the backfiring effect in a quantitative model. With aggregate OECD data, Hayakawa, Ishikawa and Tarui (2020) tests the theoretical predictions in Ishikawa and Tarui (2018) by estimating the effect of import tariffs on exports using dry bulk product tariffs as an instrument for containerized product tariffs. They interpret the round trip effect as the underlying mechanism that is driving their results. Using more detailed data, my paper provides direct empirical evidence of the round trip effect (the negative correlation in freight rates). I also show the broader economic importance of the round trip effect by quantifying the trade prediction differences between this model and a model which assumes that transport cost is exogenous.

Last but not least, the existing literature on container technology and trade have studied the impact of containerization on trade and on substitution with other modes of transport (Bernhofen, El-Sahli and Kneller, 2016; Coşar and Demir, 2018; Rua, 2014). This paper contributes by highlighting the trade and trade policy implications from the round trip effect which is a key feature of the container transport network structure.

In the next section, I present my theoretical framework and establish theoretical predictions on the round trip effect and its implications on international trade. Section 3 introduces my data. I introduce two stylized facts in Section 4 which affirm my theoretical predictions and identifies the impact of the round trip effect on transport prices using an instrument based on the round trip effect insight. Section 5 uses the instrument to estimate a trade elasticity. In Section 6, I utilizes the trade elasticity from Section 5 to estimate parameters in the model from Section 2 in order to simulate two counterfactuals—a doubling of US import tariffs on its trading partners and the impact of the Trump administration's section 301 tariffs on China. Section 7 concludes.

2 Theoretical Framework

This section presents the theoretical implications of endogenous transport costs and the round trip effect. Since the round trip effect is a general phenomenon that can come out of a variety of models, the simplest possible approach is chosen here. To highlight the trade implications of the round trip effect, my results are discussed in comparison to a model where transport costs are assumed to be exogenous (Appendix A.3.1).[11]

2.1 Model Setup

The model in this paper extends Hummels, Lugovskyy and Skiba (2009) to incorporate the round trip effect, based on Behrens and Picard (2011), and to allow for heterogeneous countries. The world consists of 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 transport firms transport the tradeable goods from producer countries to consumers.

The utility function of a representative consumer in country j is quasilinear:

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

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} is the quantity of variety from i consumed in j, while ϵ is the price elasticity of demand. The numeraire good is costlessly traded and its price is normalized to one.

Each country is perfectly competitive in producing their variety and labor is the only input to production. As such, the delivered price of country i's good in j (p_{ij}) reflects its delivered cost which is increasing in i's domestic wages (w_i), the ad-valorem tariff rate

[11] Figure A.2 (Appendix A.1) presents a graphical illustration of the round trip effect assuming linear demand and supply transport markets (Online Appendix B.2).

that j imposes on i ($\tau_{ij} \geq 1$), and the per unit transport cost from i to j (T_{ij}):

$$p_{ij} = w_i \tau_{ij} + T_{ij} \tag{2}$$

The profit function of a perfectly competitive transport firm servicing the round trip between i and j ($\pi_{\overleftrightarrow{ij}}$) is as below (Behrens and Picard, 2011):

$$\pi_{\overleftrightarrow{ij}} = T_{ij} q_{ij} + T_{ji} q_{ji} - c_{\overleftrightarrow{ij}} \max\{q_{ij}, q_{ji}\} \tag{3}$$

where q_{ij} is the quantity of goods shipped from i to j while $c_{\overleftrightarrow{ij}}$ is the marginal cost of serving the round trip between i and j like the cost of hiring a crew or renting a ship, both of which would increase with quantity. While this cost function does not include one-way expenses like loading or unloading costs and fuel, the main results would be robust to including them. Following Behrens and Picard (2011) and Hummels, Lugovskyy and Skiba (2009), one unit of transport services is required to ship one unit of good.

While the perfect competition assumption here is mostly to maintain simplicity, a number of recent factors including pro-competitive policies implemented by the Federal Maritime Comission contribute to the basis for this assumption.[12] Moreover, as discussed later on, the main results do not hinge on this assumption.

2.2 Equilibrium Conditions

As in Behrens and Picard (2011), I find 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. Nonzero freight rates in the data suggests that the first equilibrium is more relevant and hence is the focus here. However, the main results are robust to relaxing this balanced quantity assumption with a search framework (Online Appendix B.5).

[12] Additional factors include the surplus of capacity documented by the 2013 Review of Maritime Transport (UNCTAD) due to the 2008 recession and time to build lags (Kalouptsidi, 2014). Jeon (2017), which studies how demand uncertainty affects investment and welfare in the container shipping industry, finds that this industry is relatively unconcentrated based on the Herfindahl index (less than 1000).

From the transport firm's profit function in (3), the optimal freight rates on routes ij and ji will add up to equal the marginal cost of the round trip between i and j:

$$T_{ij} + T_{ji} = c_{\overleftrightarrow{ij}} \tag{4}$$

which implies that the freight rates between i and j are negatively correlated with each other conditional on the round trip marginal cost $c_{\overleftrightarrow{ij}}$. This negative relationship is affirmed in the first stylized fact later on in Section 4 (Figure 2).

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

$$X_{ij} = \left(\frac{\epsilon}{\epsilon - 1} \frac{1}{a_{ij}} \right)^{-\epsilon} \left(w_i \tau_{ij} + T_{ij} \right)^{1-\epsilon}, \ \epsilon > 1 \tag{5}$$

It is decreasing in wages in i, j's import tariffs on i, and the transport cost from i to j. This negative relationship between trade value and transport cost is empirically confirmed in my data (Table A.2).

Combining both equations (4) and (5), we can see that the trade value of country i's good in j is positively correlated with the return direction freight rates from j to i. This positive relationship is affirmed in the second stylized fact later on in Section 4 (Figure 3):

$$X_{ij} = \left(\frac{\epsilon}{\epsilon - 1} \frac{1}{a_{ij}} \right)^{-\epsilon} \left(w_i \tau_{ij} + c_{i,j} - T_{ji} \right)^{1-\epsilon}, \ \epsilon > 1 \tag{6}$$

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:

$$T_{ij}^R = \frac{1}{1 + A_{ij}} \left(c_{\overleftrightarrow{ij}} \right) - \frac{1}{1 + A_{ij}^{-1}} \left(w_i \tau_{ij} \right) + \frac{1}{1 + A_{ij}} \left(w_j \tau_{ji} \right), \ A_{ij} = \frac{a_{ji}}{a_{ij}} \tag{7}$$

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 ($c_{\overleftrightarrow{ij}}$). The second term shows that it is decreasing with the destination country j's import tariff on i (τ_{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 (τ_{ji}), as well as destination j's wages (w_j). The second term is the mitigating effect on the changes in trade demand or supply on route ij while the third term isthe spillover effect from changes on the opposite route ji.

The equilibrium price of country i's good in j is increasing in the marginal cost of round trip transport $c_{\overleftrightarrow{ij}}$, 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, which is due to the round trip effect:

$$p_{ij}^{R} = \frac{1}{1+A_{ij}} \left(w_j \tau_{ji} + w_i \tau_{ij} + c_{\overleftrightarrow{ij}} \right), \;\; A_{ij} = \frac{a_{ji}}{a_{ij}} \tag{8}$$

The equilibrium trade quantity and value on route ij are decreasing in the marginal cost of transport, both countries' wages and import tariffs:[13]

$$\begin{aligned} q_{ij}^{R} &= \left[\frac{\epsilon}{\epsilon-1} \frac{1}{a_{ij}} \frac{1}{1+A_{ij}} \left(w_j \tau_{ji} + w_i \tau_{ij} + c_{\overleftrightarrow{ij}} \right) \right]^{-\epsilon} \\ X_{ij}^{R} &= \left[\frac{\epsilon}{\epsilon-1} \frac{1}{a_{ij}} \right]^{-\epsilon} \left[\frac{1}{1+A_{ij}} \left(w_j \tau_{ji} + w_i \tau_{ij} + c_{\overleftrightarrow{ij}} \right) \right]^{1-\epsilon}, \; A_{ij} = \frac{a_{ji}}{a_{ij}} \end{aligned} \tag{9}$$

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 j increases its import tariff on country i (τ_{ij}), not only will its own imports from i be affected, but its exports to i as well.

2.3 Comparative statics

This subsection describes the trade predictions from changes in import tariffs and preferences between this model and a model with exogenous transport costs (Appendix A.3).

When country j's import tariff on country i (τ_{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 (A.1)) while its import quantity and value from i will fall (equation (A.2)). There will be no changes on the exports side.

When transportation is endogenized to take into account 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, coun-

[13] If countries are symmetric (i.e. have symmetric preferences $a_{ij} = a_{ji}$), the freight rates each way will be half the marginal cost: $T_{ij}^{Sym} = T_{ji}^{Sym} = \frac{1}{2} c_{\overleftrightarrow{ij}}$ and the countries will face the same prices, quantities, and values. See Appendix A.3 for more details.

try j's import freight rate will fall to mitigate the impact of the tariff (equation (7)). This decrease is not enough to offset j's net import price increase from i (equation (8)) which results in a fall in j's import quantity and value (equation (9)). This import fall, however, is less than the import fall in the exogenous model.

Second, the impact of j's import tariff on i will spillover 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, a 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 (equation (7)). Country j's export price to i increases from the export freight rate increase while its export quantity and value to i falls (equations (8) and (9)). The following lemma can be shown (see Appendix B.4 for proof):

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.

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

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

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

Similar results can be derived for changes in country's preferences (Appendix A.3.3). In general, there are two main differences between the round trip model and the model with exogenous transport costs. 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 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. 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. *Under the assumption of competitive transport firms,*

(i) When transport costs are endogenous and determined on a round trip basis under the interior solution equilibrium, increases in import tariffs τ_{ij} decreases both equilibrium imports from and exports to the same partner: $\frac{\partial X_{ij}^R}{\partial \tau_{ij}} < 0$ and $\frac{\partial X_{ji}^R}{\partial \tau_{ij}} < 0$

(ii) When transport costs are endogenous and determined on a round trip basis under the interior solution equilibrium, an increase in preference shock a_{ij} increases both equilibrium imports from and exports to the same partner: $\frac{\partial X_{ij}^R}{\partial a_{ij}} > 0$ and $\frac{\partial X_{ji}^R}{\partial a_{ij}} > 0$

(iii) When transport costs are exogenous, there are only changes in imports and no corresponding changes in exports: $\frac{\partial X_{ij}^{Exo}}{\partial \tau_{ij}} < 0$, $\frac{\partial X_{ji}^{Exo}}{\partial \tau_{ij}} = 0$, $\frac{\partial X_{ij}^{Exo}}{\partial a_{ij}} < 0$ and $\frac{\partial X_{ji}^{Exo}}{\partial a_{ij}} = 0$

(iv) The relative import changes are larger from import tariffs or preference changes when transport costs are exogenous: $\frac{\partial \left| X_{ij}^{Exo}/\partial \tau_{ij} \right|}{\partial \left| X_{ij}^{R}/\partial \tau_{ij} \right|} > 0$ and $\frac{\partial \left| X_{ij}^{Exo}/\partial a_{ij} \right|}{\partial \left| X_{ij}^{R}/\partial a_{ij} \right|} > 0$

The main results above are robust and continue to hold when the key assumption—balanced quantity—is relaxed. I show this by extending Chaney (2008) to include the round trip effect and a search framework between transport firms and exporting firms which allows for containerships to be at less-than-full capacity on either legs of a route (Miao, 2006). As a result, I can relax the assumption transport quantities have to be the same (see Online Appendix B.5 for further details). 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 which 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. This search process also smooths the relationship between price and quantity relative to the trade shocks which renders the balanced quantity assumption unnecessary. Given this framework, the main spillover predictions continue to hold (Proposition 3, Online Appendix B.5). When allowing for imperfect competition, the main mitigating and spillover results continues to hold. However, these effects could be larger or small, depending on whether the demand specification's pass-through is greater or less than 1 (Proposition 2, Appendix A.4).

In addition, Ishikawa and Tarui (2018) is an applied theory paper which finds the same spillover results with an oligopolistic transportation model. Focusing on intermediate goods, Mostashari (2011) 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 these tariff cuts reduce the cost of their imported intermediate goods which makes their exports, using these intermediate goods, relatively more competitive.

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 due to the balanced trade condition in a general equilibrium setting. I highlight 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. These findings are in line with Costinot and Werning (2019) who show that trade balance is not a necessary or sufficient condition for the Lerner Symmetry to hold.

3 Data

Container shipping is a $6 trillion industry that is responsible for transporting more than 95% of the world's manufactured goods (Wall Street Journal, 2015) and two-thirds of total world trade by value (World Shipping Council). In the US, container shipping accounts for almost two-thirds of vessel trade in 2017.

3.1 Background

Drewry Maritime Research (Drewry) compiles monthly port-level container freight rate data from importer and exporter firms located globally.[14] This novel data set, to the best of my knowledge, is the only source of container freight rates on major global routes. These ports are the largest globally, handling more than one million containers annually, and are a subset of all operating container ports. Container cargo handling is very concentrated at major ports, where the combined container traffic at the world's top 20 container ports accounts for about 50 percent of the world's total (UNCTAD, 2011). My dataset covers 12 of these 20 ports, accounting for a majority of the world's leading container ports.

The high level of disaggregation in this data set—at the monthly and port-level—has three main benefits. First, it can shed light on our understanding of how freight rates vary across these major global routes and across relatively high frequency. The fact that the Drewry data set is based on actually-paid freight rates is very valuable since there are other freight rate sources that artificially generate part of their freight rates data from algorithms.[15] Second, this detailed data set allows for the first contribution of the paper—the empirical identification of the round trip effect. Previous papers have relied on much more aggregated data and are not able to convincingly establish the presence of the round trip effect. Third, this high degree of disaggregation allows me to utilize the round trip effect as a novel IV strategy to estimate a short-run trade elasticity with respect to transport costs—the second contribution of this paper. I am also able to exploit the panel nature of this data in my empirical estimations to control for confounding factors.

These freight rates are spot market rates for a standard 20-foot container. While spot market and longer-term contract rates are both present in container markets, I choose to focus on spot market rates for two main reasons. The first is data availability. Contract rates are filed confidentially with the Federal Maritime Commission (FMC) and are protected against Freedom of Information Act (FOIA) requests. Second, persistent overcapacity during my sample period resulted in a variety of linkages between contract and spot rates. Both these reasons suggest that spot prices play a major role in informing

[14]Many thanks to Nidhin Raj, Stijn Rubens, and Robert Zamora at Drewry for their help. These freight rates represent the lower bound of total transport costs since they do not include the cost of inland transport.

[15]One example is worldfreightrates.com.

longer-term contracts and are the best alternative currently available, to my knowledge, to shedding light on container transport markets as well as the the round trip effect (see Appendix A.2 for further details).

In order to compare apples to apples, I match my data set to trade in containers. Monthly containerized US trade data at the port level comes from the Census Bureau, USA Trade Online, at the six-digit Harmonized System (HS) product code level.[16] It includes the trade value and weight between US ports and its foreign partner countries.

For the US, Drewry collects freight-rate data on the three of its largest container ports (Los Angeles and Long Beach, New York, and Houston). All combined, these ports handle 16.7 million containers annually—more than half of the annual US container volume (MARAD). Since my freight rates data is at the port-to-port level, I aggregate it to the US port and foreign country level to match the containerized trade data (Appendix A.2 elaborates). The level of observation in the combined data set is at the US port, foreign partner country, and product level. This combined data set accounts for the majority of all US vessel trade and spans January 2011 to June 2016.[17] While these port-pairs are the largest globally, this data set covers a subset of all the ports globally–there are 21 foreign countries in this data set.[18] This is a conservative estimate since Drewry has indicated that their freight rates data can be applied to adjacent ports.[19] Figure 1 plots the ports in my data set, which are circled black. Overall, the ports in this data set are 21 of the largest foreign ports handling more than 500 million tons of cargo volume annually with

[16]Containerized trade data is not readily available for all other countries apart from the United States which limits my analysis to US trade in this paper.

[17]Shipping vessels that carry trade without containers include oil tankers, bulk carriers, and car carriers. Bulk carriers transport grains, coal, ore, and cement.

[18]The port pairs are between three US ports (New York, Houston, Los Angeles and Long Beach) and the following ports: Australia (Melbourne), Brazil (Santos), China, Hong Kong, India (Nhava Sheva), Japan (Yokohama), Korea (Busan), Malaysia (Tanjung Pelepas), New Zealand (Auckland), North Continent Europe (Rotterdam), Philippines (Manila), Russia (St Petersburg), Singapore, South Africa (Durban), Taiwan (Kaohsiung), Thailand (Laem Chabang), Turkey (Istanbul), U.A.E (Jebel Ali), UK (Felixstowe), Vietnam (Ho Chi Minh), and West Med (Genoa).

[19]Drewry made the strategic decision to collect one set of data on ports that are close together. Examples of these include Long Beach and Los Angeles, as well as the ports surrounding Rotterdam. The reason for this, according to them, is because freight rates are similar across these ports. One example is the data for the port of Rotterdam. According to Drewry, this port represents the "Hamburg-Le Havre range" which means that its data is representative of the data for Antwerp (Belgium), Le Havre (France), Hamburg (Germany), Zeebrugge (Belgium), and Bremerhaven (Germany). However, I have not done this in order for the port matches to be accurate and to avoid the Rotterdam Effect. As such, Belgium, France, and Germany are not in my data set.

at least one port per continent (larger circles indicate larger ports measured by annual cargo volume). These ports are also part of the busiest routes as indicated by the thick lines connecting them (the lines between the ports indicate the frequency of shipping routes, where thicker lines mean busier routes). I have at least one port in each continent with more ports concentrated in Asia due to the presence of larger ports in that region.

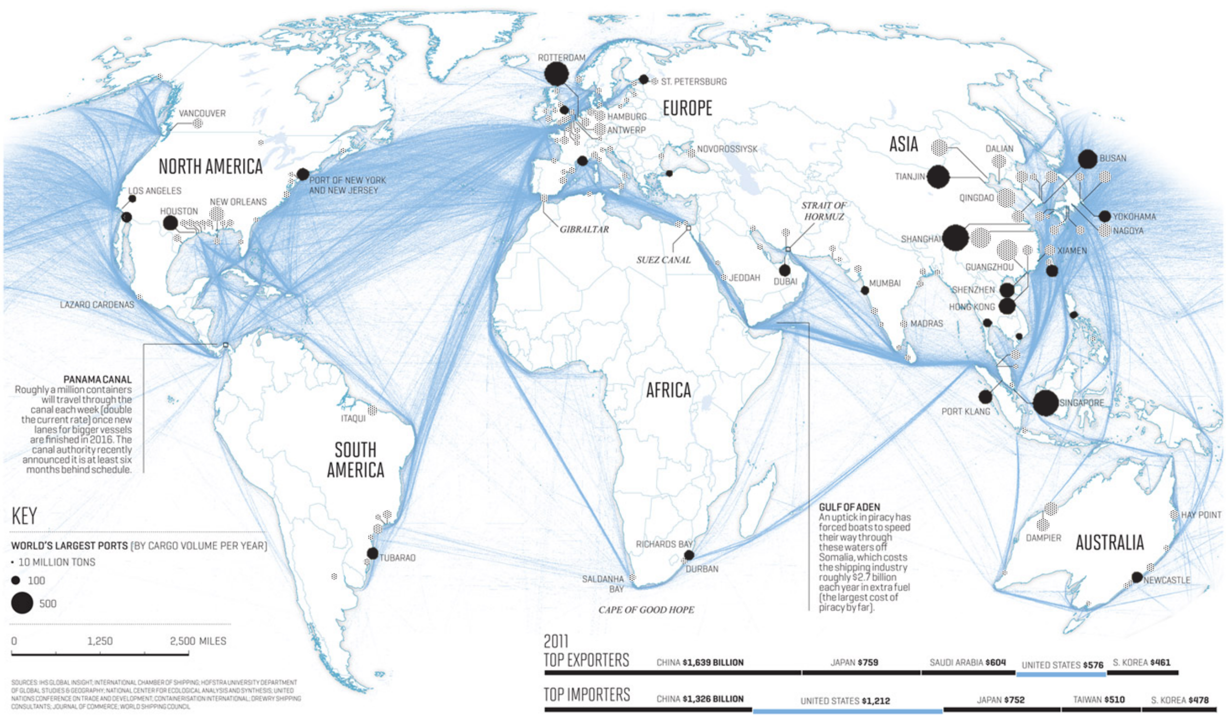

Figure 1: Container ports and their shipping routes in dataset

Notes: The black circles indicate the ports in the data set and the shaded circles indicate other container ports. Larger circles indicate larger container volumes per year, where the largest circles mean that the port handles 500 million tones of cargo annually. The blue lines indicate shipping routes where thicker lines mean busier routes. There are 21 foreign ports (20 in the figure since Port of Auckland, New Zealand is excluded) and 3 US ports in total.
Source: Nicholas Rapp, Fortune Magazine, May 2012, and author's highlighting of ports. ■

The combined data coverage includes the net freight rates, trade value, and trade weight to ship from i to j, regardless of whether it is a direct or indirect route. My freight rates data from Drewy is based on the actual rates paid by freight forwarders and companies to ocean carriers in order to ship their cargo between particular port-pairs. Similarly, my trade data from the Census Bureau includes coverage on merchandise shipped in transit through the United States from one foreign country to another, in addition to direct coverage on movement of merchandise between the United States and foreign countries.

As a result of capturing both direct and indirect routes, this data also includes transshipments. This is to the extent that the port that these goods are moving through is a hub port. It is important to note, however, that the 21 foreign ports in this data set are a mix of transshipment and large ports. While some of these ports are well known transshipment hubs like (Singapore, Rotterdam, and Hong Kong), most of these ports are in relatively large trading countries (like the UK, Australia, and Russia) with some playing a role in both like China.[20]

3.2 Summary Statistics

Table 1 presents the summary statistics for the matched data set which is broken down by US exports, US imports, and total US trade. These variables are on average higher 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 is also on average higher than US exports. These patterns are robust to using data on container volumes (table A.10).

Table 1: Summary statistics

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

Notes: Standard deviation in parentheses. Observation at the US port-foreign country level. There are 3 US ports and 21 foreign countries but the Drewry freight rates data does not start at Jan 2011 for all routes. Imports excludes U.S. import duties, freight, insurance, and other charges incurred in bringing the merchandise to the U.S. Exports are valued on a free alongside ship basis.
Source: Drewry, Census Bureau, and author's calculations. ■

Between port pairs, the average gap in container freight rates between port pairs is 1.95 with wide variation (panel (A), figure A.5). This shows that freight rates are not

[20] Ganapati, Wong and Ziv (2020) finds that both well-known hub ports and large trading countries have more direct trade with the US. Direct trade can be measured in terms of share of non-transshipped volume or the number of stops a containership makes before arriving at its destination.

symmetric—entirely explained by distance or fixed bilateral characteristics—for the majority of port pairs. In fact, I find a link between asymmetric freight rates and asymmetric demand between locations. For example, 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, Drewry Maritime Research). 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). Panel (B) shows this positive correlation: 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 (figure A.5). This positive relationship is also present using container volumes (figure A.3).

4 Impact of the Round Trip Effect on Freight Rates

In this section, I introduce two stylized facts which provide empirical evidence of the round trip effect based on my theoretical predictions. Next, since trade and freight rates are endogenously determined, I introduce an instrument based on the round trip insight to establish the impact of the round trip effect on freight rates.

4.1 Stylized Facts

Stylized Fact 1. *A positive deviation from the average freight rates from i to j is correlated with a negative deviation from the average opposite direction freight rates from j to i.*

This inverse relationship, using just the freight rates data set, is the result of regressing the freight rates between port pairs on each other controlling for time trends and route characteristics.[21] Figure 2 presents a visual representation of this regression by first regressing the freight rates on time and route fixed effects, collecting the residuals, then graphing the T_{ijt} residuals on T_{jit} (its opposite direction counterpart). Table A.1 presents the regression results.

[21] 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.1 for further details.

I find that 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 result is robust to using port distances instead of route fixed effects (table A.1). This result is also robust to restricting the sample to routes that are more balanced or imbalanced, with the imbalanced routes having a slightly higher negative correlation intuitively since the backhaul problem is relatively more severe for these routes (Columns (3) and (4), table A.1).[22] This latter result shows that the backhaul problem is a necessary but not sufficient condition for the round trip effect.

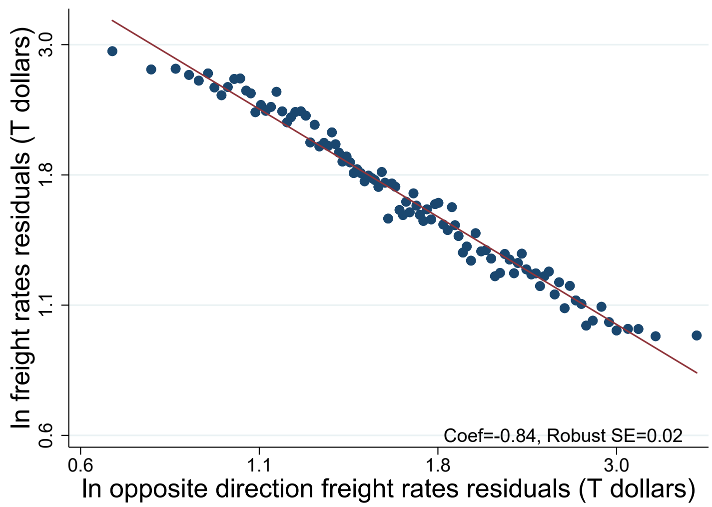

Figure 2: Residualized plot of correlation between freight rates within port pairs
Notes: Binned scatter plot with observation at the route-month level (3210 obs). Robust standard errors clustered by route with time and route controls. The y-axis variable, ln freight rates residuals, is defined as $\hat{\varepsilon}_{ijt} = \ln T_{ijt} - \hat{\gamma}_t - \hat{d}_{ij}$ where $\hat{\gamma}_t$ and $\hat{d}_{ij}$ are time and route-level controls respectively. The x-axis variable is its opposite direction counterpart. Table A.1 presents the regression results.
Source: Drewry and author's calculations.

This negative relationship is not typically predicted in the trade literature. If freight rates can be approximated by distance and therefore are symmetric, as assumed in some of the literature, the route fixed effects would absorb all the variation in the data. 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

[22] More balanced routes are defined as routes that are in the second and third quartiles of the US trade imbalance distribution from year 2003—at least 8 years prior to the start of my data. More imbalanced routes are in the first and fourth quartiles of the distribution.

costs would not be constant—as I show in Figure A.5. 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 directions depending on the demand levels—as I show in figure 2.[23] I confirm both his caveats here.

This next stylized fact shows that a country's imports and exports with a particular partner are linked via their outgoing and return transport costs:

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

This relationship is made up of two components. First, intuitively, trade value and weight from j to i decrease with freight rates on the same route (table A.2). Second, freight rates are negatively correlated within a route as established in the first stylized fact. As such, freight rates from i to j *increases* with opposite direction trade value (j back to i, Figure 3). The opposite relationship applies for value per weight due to the first component of the linkage being positive—value per weight increases with freight rates.

Specifically, within a dyad, a one percent deviation from the average opposite direction trade value (from j to i) is correlated across time with about a 0.1 percent increase in average freight rates in the going direction from i to j (column (1), Table 2 and Figure 3). In column (2), a within dyad one percent increase from the average opposite direction trade weight is correlated across time with about a 0.1 percent increase in average freight rates in the going direction. This relationship is inverted with value per weight: a one percent increase from opposite direction value per weight is correlated with an almost 0.2 percent *decrease* in average freight rates.

These findings again provide evidence for 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.

One potential concern about these results is that the dominance of processing trade

[23]The relationship in figure 2 is not solely driven by systematic currents and wind conditions since Chang et al. (2013) estimates only a modest amount of time savings (1 to 8 percent) when ships utilize strong currents or avoid unfavorable currents in the North Pacific.

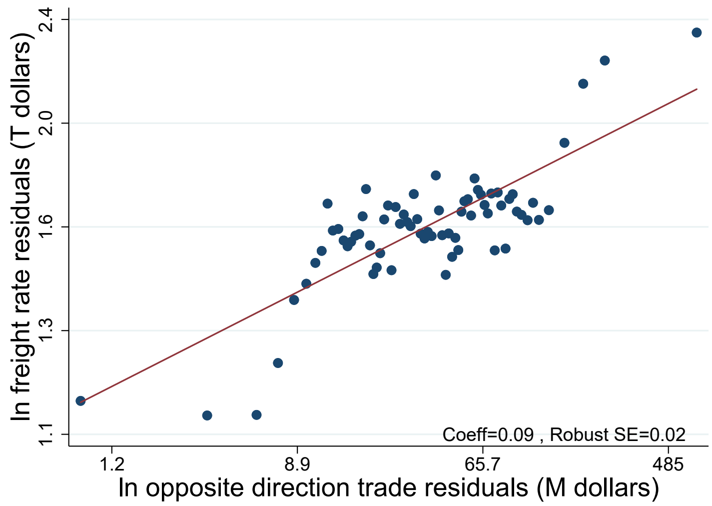

Figure 3: Residualized plot of correlation between containerized trade value and opposite direction freight rates

Notes: Binned scatter plot with observation at the route-month level (5268 obs). Robust standard errors clustered by route with time and dyad controls. The y-axis variable, ln freight rates residuals, is defined as $\hat{\varepsilon}_{ijt} = \ln T_{ijt} - \hat{\gamma}_t - \hat{d}_{\overleftrightarrow{ij}}$ where $\hat{\gamma}_t$ and $\hat{d}_{\overleftrightarrow{ij}}$ are time and dyad-level controls respectively. The x-axis variable, ln opposite direction trade value residuals, is defined as $\hat{\varepsilon'}_{ijt} = \ln X_{jit} - \hat{\gamma}_t - \hat{d}_{\overleftrightarrow{ij}}$. Regression results are in Table 2, Column (1).
Source: Drewry, Census Bureau, and author's calculations. ■

can contribute to this relationship, however these results are robust to removing the main country that conducts processing trade with the US—which is China (Columns (4) to (6), table 2).[24] Additionally, another potential concern could be systematic supply chain linkages between countries generally. I show that these results are also robust to this concern by removing products whose production process is typically fragmented (Columns (7) to (9), table 2). Fort (2017) constructs a data set on plant-level decisions to fragment production in the US at the four-digit NAICS industry level.[25] Using the industries that she has identified, 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. In the presence of hub and spoke networks as well as transshipments, my results could potentially be a lower bound (see Appendix

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

[25] Examples of these industries include computers, communications equipment, and engines. For more information, see table A.5 in Fort (2017).

Table 2: Regression of freight rates on opposite direction trade

ln Freight Rates	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
ln Opp Direction Value	0.0909			0.116			0.0887		
	(0.0227)			(0.0188)			(0.0230)		
ln Opp Direction Weight		0.122			0.127			0.121	
		(0.0178)			(0.0173)			(0.0181)	
ln Opp Direction Value/Wgt			-0.160			-0.107			-0.172
			(0.0417)			(0.0365)			(0.0421)
Observations	5684	5684	5684	5294	5294	5294	5684	5684	5684
R^2	0.523	0.557	0.518	0.564	0.586	0.519	0.520	0.555	0.523
F	15.97	47.22	14.72	37.80	54.29	8.693	14.82	45.04	16.72
Without China				Y	Y	Y			
Without Fragmented Goods							Y	Y	Y

Notes: Robust standard errors clustered by route in parentheses. Time and dyad level fixed effects are included for each regression. Columns (4) to (6) replicates the regressions in (1) to (3) but without China. This results in a smaller number of observations relative to the other specifications. Columns (7) to (9) replicates the regressions in (1) to (3) but without products that are typically fragmented in the production process.
Source: Drewry, Census Bureau, and author's calculations. ■

Section A.2 for further details).

4.2 Identification of Round Trip Effect Impact on Freight Rates

These stylized facts have provided correlations between port-pair freight rates as well as opposite direction trade and freight rates, which establishes empirical evidence for the presence of the round trip effect. However, in order to identify the impact of the round trip effect on freight rates, I need to show a causal relationship between opposite direction trade from j to i and freight rates from i to j. I require an IV that captures exogenously driven shocks to trade from j to i.

My proposed IV is a transport supply shifter. Cost shocks from j to i that affects its supply of containers will impact its corresponding freight rates on the same route. These changes to freight rates from j to i will induce an opposite shift to the freight rates from i to j due to the round trip effect. For example, a positive cost shock on the opposite direction route ji will decrease its corresponding transport supply. As transport supply on route ji declines, its corresponding freight rates will increase. Through the negative correlation in freight rates from the round trip effect, this induces a decrease in route ij freight rates.

This traces the positive relationship between aggregate opposite direction trade from j to i (X_{jit}) and freight rates from i to j (T_{ijt}) which has been established in Stylized Fact 2.

Using X_{jit} directly to identify changes in T_{ijt} is problematic, however, if cost shocks between countries i and j are not independent. Examples of this violation include treaties between these countries which affects their bilateral trading costs (like free trade agreements or harmonization of standards), exchange rate fluctuations, or processing trade. As such, I introduce an instrument, in the spirit of Bartik (1991), that predicts the opposite direction trade on route ji but is independent of the unobserved cost factors on route ij.

4.2.1 Instrumental Variable

To construct my instrument, I start by showing a series of transformations on country j's total exports to i at time t (X_{jit}). Total exports 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:

$$X_{jit} = \sum_N X_{jint} = \sum_N X_{jAnt} \times \frac{X_{jint}}{X_{jAnt}} \equiv \sum_N X_{jAnt} \times \omega_{jint} \tag{10}$$

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 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:

$$Z_{jit} \equiv \sum_N X_{j,A\backslash i,nt} \times \frac{X_{jin0}}{X_{jAn0}} \equiv \sum_N X_{j,A\backslash i,nt} \times \omega_{jin0} \tag{11}$$

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 ($X_{j,A\backslash i,nt} = \sum_A X_{jAnt} - X_{jint}$). I restrict my instrument group (set A) to high-income OECD countries following Autor, Dorn and Hanson (2013) as well as Autor et al. (2014). The second term is j's lagged product-level export shares to i, at least eight years prior in January 2003 (time 0). Instrument Z_{jit} is obtained by summing both these terms across all products.

This instrument Z_{jit} (equation (11)) differs from the expression in (10) in two respects. First, in place of the present-time product trade shares—the first term in (10), 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.[26]

4.3 Results

Using my instrument, I estimate the following equation in order to establish the impact of exogenously-driven shocks to opposite direction route ji trade on route ij freight rates:

$$\ln T_{ijt} = \beta \ln Z_{jit} + \rho_{it} + \sigma_{jt} + \delta_{\overleftrightarrow{ij}} + \iota_{ijt} \tag{12}$$

where T_{ijt} is the freight rates on route ij at time t and Z_{jit} is the instrument which predicts trade on opposite route ji at time t. I control for the time-varying propensities to export and import with exporter-time fixed effects ρ_{it} and importer-time fixed effects σ_{jt} respectively. Additionally, I control for fixed bilateral characteristics between i and j with a dyad-level fixed effect $\delta_{\overleftrightarrow{ij}}$ which takes into account time-invariant factors like distance. ι_{ijt} is the error term and standard errors are clustered at the route level to account for heteroskedasticity and serial correlation in the errors within routes.

In order for this IV strategy to be valid, the predicted trade measure on route ji has to be generally uncorrelated with unobserved cost determinants of ij direction freight rates ($\text{corr}(Z_{jit}, \iota_{ijt}) = 0$). Since the construction of the instrument excludes all present-time trade on the ji direction, the instrument abstracts from any bilaterally correlated present-time shocks between i and j like bilateral treaties or exchange rate fluctuations which were mentioned above.

Controlling for constant bilateral differences across routes, as well as time-varying importer and exporter characteristics, a 10 percent increase in the opposite direction trade measure corresponds to a significant and positive 0.4 percent increase in freight rates (Fig-

[26] 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.

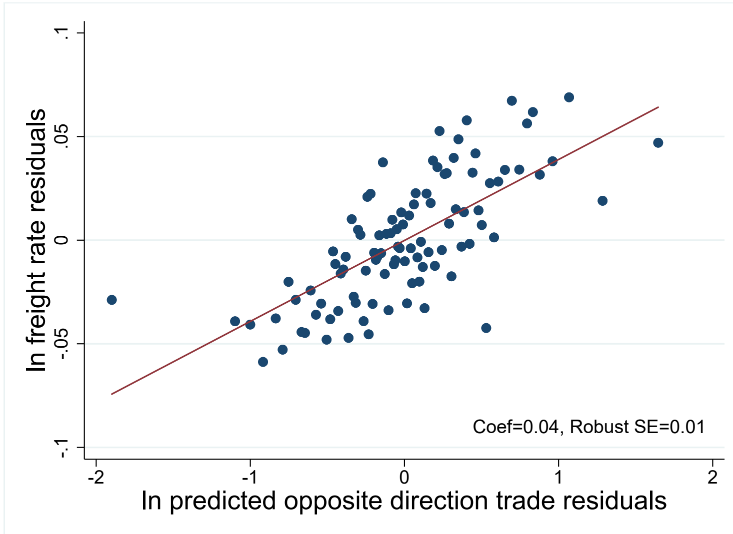

Figure 4: Residualized plot of correlation between freight rates and instrument

Notes: Binned scatter plot with observation at the route-month level (2307 obs). Robust standard errors clustered by route with dyad, importer-time, and exporter-time controls. The y-axis variable, ln freight rates residuals, is defined as $\hat{\iota}_{ijt} = \ln T_{ijt} - \delta_{\overleftrightarrow{ij}} - \hat{\rho}_{it} - \hat{\sigma}_{it}$ (equation (12)). The x-axis variable, ln predicted opposite direction trade residuals, is defined as $\hat{\iota'}_i jt = \ln Z_{jit} - \delta_{\overleftrightarrow{ij}} - \hat{\rho}_{it} - \hat{\sigma}_{it}$. Regression results are in Table 3.
Source: Drewry, Census Bureau, and author's calculations. ■

ure 4 and Table 3). This result is robust to supply chain concerns and base year changes. In order to address the concern of systematic supply chain linkages, I remove products that are typically fragmented in the production process from the instrument construction using the industries identified by Fort (2017) (Column (2), Table 3). The estimates retain the same sign and are within one confidence interval of the baseline results. The removed products constitute about 13 percent of total trade value ($229 billion) which contribute to lower significance levels of the results. This result is also robust to an alternative base year. I reconstructed the instrument with January 2009 weights and find that my results have the same sign and are within one standard error of the baseline results (Column (3), Table 3). This 2009 instrument has a higher significance level since it is constructed with a more recent base year relative to the start of my sample and therefore is more correlated with my sample period.

These results establishes the conclusive link between opposite direction predicted trade and freight rates, providing in some sense the best "test" of the round trip effect on prices.

Table 3: Regression of freight rates on predicted opposite direction trade

	(1) ln Freight Rate	(2) ln Freight Rate	(3) ln Freight Rate
ln Opp Direction Predicted Trade	0.0391	0.0245	0.0515
	(0.0138)	(0.0143)	(0.0114)
Ex-Time & Im-Time FE	Y	Y	Y
Dyad FE	Y	Y	Y
Observations	2307	2307	2326
R^2	0.964	0.963	0.965
F	7.969	2.954	20.43
Without Fragmented Goods		Y	
2009 Base Year			Y

Notes: Robust standard errors in parentheses are clustered by route. The predicted trade instrument is constructed at the HS4 level with Jan 2003 data using only OECD countries. Column (1) has route, exporter-time, and importer-time controls. The instrument in Column (2) is constructed without products typically fragmented in the production process. Regression is run on OECD countries. The instrument in Column (3) is constructed using Jan 2009 weights.
Source: Drewry, Census Bureau, sea-distance.org, and author's calculations. ■

5 Trade Elasticity Estimation

This section presents my strategy for estimating a containerized trade elasticity with respect to transport prices. I introduce my estimating equation, explain the endogeneity issue from an ordinary least squares (OLS) estimation, and detail how the IV introduced in the previous section can address the potential biases. I then present the main results and robustness checks, followed by a discussion on how my trade elasticity estimates compare to the literature.

5.1 Identification of the impact of freight rates on trade

My estimating equation is loosely based on the canonical gravity equation (Head and Mayer, 2014):[27]

$$\ln X_{ijnt} = \alpha \ln T_{ijt} + S_{it} + M_{jt} + d_{\overleftrightarrow{ijn}} + \varepsilon_{ijnt} \tag{13}$$

[27]The lack of price data hinders using a model-implied equation (equation (6)). Instead, I estimate the elasticity of trade with respect to freight rates: $\frac{\partial X_{ij}}{\partial T_{ij}} \frac{T_{ij}}{X_{ij}}$.

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.[28] 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}). Both fixed effects also absorb aggregate time-varying shocks to these countries.

The dyad-by-product level fixed effect, $d_{\overleftrightarrow{ijn}}$, 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.[29] $d_{\overleftrightarrow{ijn}}$ 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.6). The error term is ε_{ijnt}. Standard errors are clustered at the route level to account for general forms of heterokedasticity and serial correlation in the errors within a route. In my results, I include an additional specification with separate controls for dyad ($d_{\overleftrightarrow{ij}}$) and product ($\gamma_n$) fixed effects.

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 high frequency transportation-mode specific panel data and its corresponding observed transport cost to identify a mode-specific trade elasticity with respect to transport cost. The 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, α, is the parameter of interest here. As mentioned earlier, the main challenge for this exercise is that con-

[28] Container freight rates are not product specific because pricing in shipping services are generally by a combination of volume and weight.

[29] 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.

tainer freight rates and trade are jointly determined. As such, an OLS estimation of α in (13) 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 ε_{ijnt} will simultaneously increase freight rates T_{ijt} and containerized trade X_{ijnt}. This results in a positive correlation between T_{ijt} and X_{ijnt} 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_{ijnt}.[30] In order to consistently estimate α, 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, Online Appendix B.2). A positive trade shock on the opposite direction route ji in the top graph of figure A.2 increases its corresponding transport demand. As transport supply on that route (ji) responds, the aggregate transport supply in the original direction (route ij) will also increase due to the round trip effect. 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 (13) 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 utilize the Bartik-type instrument introduced in the previous section (equation (11)) that

[30] It is 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.4).

predicts the opposite direction trade on route ji but is independent of the unobserved demand determinants on route ij. The first stage of the 2SLS regression has been established in the previous section (equation (12)).

5.2 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_{ijt} 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 (ε_{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 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 (11)). 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, 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. This robustness check also helps address concerns about hub and spoke networks as well as transshipments.

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 ε_{ijnt}—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 ji 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.

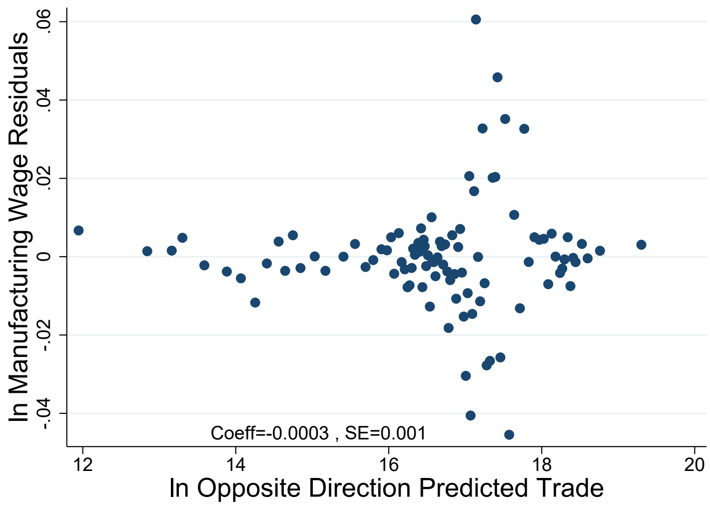

Figure 5: Residualized plot of correlation between instrument and an approximation of demand determinants using manufacturing wages

Notes: Binned scatter plot at the country-year level with 1262 obs. F-stat 0.07.
Source: Drewry, Census Bureau, OECD, and author's calculations. ■

5.3 Main Results

Panel A in in table 4 presents the containerized trade value estimates.[31] 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 (Panel A, 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. Panel A 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 (Panel A, 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. This magnitude difference is in line with Baier and Bergstrand

[31]The first stage results from the 2SLS regression in Table A.3 are slightly different from the results in the previous section (Table 3 and Figure 4). This is due to differences in levels of observation. The former is at the product-route-time level while the latter is at the route-time level.

(2007), who find a similar five-fold increase in the effect of free trade agreements on trade flows after taking into account of the endogeneity of FTAs.

Table 4: Containerized trade elasticity with respect to freight rates

	(1) OLS	(2) OLS	(3) IV	(4) IV
Panel A: ln Trade Value				
ln Freight Rate	-0.676	-0.520	-3.651	-2.795
	(0.148)	(0.133)	(0.949)	(0.903)
Panel B: ln Trade Weight				
ln Freight Rate	-1.061***	-0.837***	-4.790***	-3.631***
	(0.196)	(0.177)	(1.126)	(0.969)
Panel C: ln Trade Value per Weight				
ln Freight Rate	0.384***	0.317***	1.138***	0.836***
	(0.0695)	(0.0681)	(0.224)	(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

Notes: Robust standard errors in parentheses are clustered by route. 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. 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. Table A.3 presents the first stage regressions. Sources: Drewry, Census Bureau, and author's calculations. ■

Panel B in table 4 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 Panel B 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 (Panel B, Column (2)). In my IV estimates, a one percent increase in container freight rates decreases containerized weight by 4.8 percent (Panel B, 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 (Panel B, Column (4)). While the IV estimates here are not directly comparable to the literature, my OLS containerized trade weight estimates are within the range of previously established volume elasticities for other transport modes: air, truck, and rail (De Palma et al., 2011; Oum, Waters and Yong, 1992).[32]

Panel C in table 4 presents the containerized value per weight elasticity with respect to freight rates results. This unit value calculation provides a crude measure 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 Panel C Column (1) shows that a one percent increase in container freight rates increases the average value per weight in containers by about 0.4 percent. When controlling for dyad-by-products, a one percent increase in freight rates increases trade value per weight by 0.3 percent (Panel C, Column (2)). In my IV estimates, a one percent increase in freight rates increases containerized value per weight by 1.1 percent (Panel C, Column (3)). This estimate decreases slightly with dyad-by-product controls—a one percent increase in freight rates increases containerized value per weight by 0.8 percent (Panel C, Column (4)). My value per weight IV estimates are within the range of the estimates from Hummels and Skiba (2004) who finds a price elasticity with respect to freight cost between 0.8 to 1.41.

5.3.1 Robustness Checks

These results are robust to a number of alternative specifications. These include removal of products typically constructed in supply chains, aggregation of time period, different product classifications, trade route imbalances, aggregation up to the route-level, expansion of sample size, as well as change of base year. These results are also robust to alternative levels of clustering—at the route and product, dyad (two-way route), and dyad with products levels.

As mentioned earlier, the systematic presence of supply chains can potentially threaten my identification strategy. Removing the industries identified by (Fort, 2017) as products typically fragmented in the production process, I find that my estimates retain the same

[32]The OLS volume elasticities in these studies are between -0.8 to -1.6 (air), -0.7 to -1.1 (truck), and -0.4 to -1.2 (rail).

sign and are within the confidence interval of my baseline results (table 5). As previously mentioned, the removed products make up about 13 percent of the total containerized value trade which contribute to the lower significance levels of my results and loss of instrument power.

Table 5: Containerized trade elasticity with respect to freight rates: without products typically fragmented in the production process

	(1) OLS	(2) OLS	(3) IV	(4) IV
Panel A: ln Trade Value				
ln Freight Rate	-0.533	-0.467	-5.979	-4.346
	(0.0980)	(0.111)	(2.695)	(2.023)
Panel B: ln Trade Weight				
ln Freight Rate	-0.724	-0.643	-7.769	-5.978
	(0.118)	(0.133)	(3.452)	(2.689)
Panel C: ln Trade Value per Weight				
ln Freight Rate	0.191	0.176	1.790	1.631
	(0.0358)	(0.0375)	(0.808)	(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

Notes: Robust standard errors in parentheses are clustered by route. Products that are typically fragmented in the production process (as identified in Fort (2017) are removed from sample and the instrument. 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. Table A.4 presents the first stage regressions.
Sources: Drewry, Census Bureau, and author's calculations. ■

Since my data is at the monthly period, the magnitude of 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 find that this is indeed the case: aggregating my monthly estimation to quarterly, bi-annually, and annually decreases its magnitude (Table 6) Between the monthly and annually time periods, my elasticity decreased by almost half (45%) (calculated from columns (1) and (4), Table 6). This decrease in elasticity as time period aggregation increases is also found in other studies (Shapiro, 2015; Steinwender, 2018).

Table 6: Containerized trade elasticity with respect to freight rates by time period

	(1)	(2)	(3)	(4)
Freight Rate	-2.795	-1.920	-1.645	-1.550
	(0.903)	(0.819)	(0.938)	(0.855)
Regression	IV	IV	IV	IV
Time Period	Monthly	Quarterly	Bi-Annually	Annually
Ex-Time & Im-Time FE	Y	Y	Y	Y
Dyad-Product FE	Y	Y	Y	Y
Observations	116887	54174	29729	17566
KP-F Stat	10.70	22.57	23.63	55.69

Notes: Robust standard errors in parentheses are clustered by route. 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 2003 data using only OECD countries. Second stage is run on OECD countries as well. Ex-Time FE is exporter country and time fixed effects; Im-Time FE is importer country and time fixed effects. The time fixed effects are aggregated in each column according to the information in "Time Period." Column (1) is the baseline results from Column (4) Table 4.
Source: Drewry, Census Bureau, and author's calculations. ■

I further evaluate these estimates by comparing the different types of containerized goods. The Rauch (1999) test predicts that the demand for homogeneous goods should be relatively more elastic compared to differentiated 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 find that my results are indeed consistent with this test—my elasticity for homogenous goods are relatively higher than the baseline while the elasticity for differentiated goods are relatively lower (Columns (2) and (3), Table 7). Shapiro (2015) finds the same magnitude differences in his elasticities after dividing his sample into these product classifications.

Additionally, I show that these results are not driven by countries with which the US has a large trade imbalance with (like China). Routes with larger trade imbalances are more likely to be impacted by the round trip effect since they face a more severe backhaul problem. I find that my results are robust to restricting the sample to countries that US have relatively more balanced trade with in year 2003, at least 8 years prior to the analysis. My results are within one standard error to the baseline (Column (4), Table 7).

Last but not least, these results are robust to expansion of sample size (Table A.5), aggregation up to the route level (Table A.7), as well as an alternative base month (using

Table 7: Containerized trade elasticity with respect to freight rates: robustness

	(1) Baseline	(2) Homogeneous	(3) Differentiated	(4) Balanced
Panel A: ln Trade Value				
Freight Rate	-2.795	-4.011	-2.689	-2.787
	(0.903)	(1.419)	(1.001)	(1.172)
Panel B: ln Trade Weight				
Freight Rate	-3.631	-4.957	-3.406	-3.916
	(0.969)	(1.535)	(1.067)	(1.406)
Panel C: ln Trade Value per Weight				
Freight Rate	0.836	0.947	0.716	1.129
	(0.226)	(0.445)	(0.250)	(0.327)
Ex-Time & Im-Time FE	Y	Y	Y	Y
Dyad-Product FE	Y	Y	Y	Y
Observations	116887	45889	63816	63148

Notes: Robust standard errors in parentheses are clustered by route. 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. Second stage is run on OECD countries as well. Ex-Time FE is exporter country and time fixed effects; Im-Time FE is importer country and time fixed effects. Column (1) is the baseline results from Column (4) Table 4, Column (2) is restricted to homogenous and reference-price goods from Rauch (1999), Column (3) is restricted to differentiated goods from Rauch (1999), and Column (4) excludes the top and bottom quartile of trade imbalance distribution from year 2003.
Source: Drewry, USA Trade Online, and author's calculations. ■

January 2009 data, Table A.8).[33] All these estimates have the same signs and are within one confidence interval of my baseline estimates.

5.4 Trade Elasticity and Discussion

As predicted by the theory model (equation (5)), the elasticity of trade with respect to transport cost is the following:

$$\frac{\partial X_{ijt}}{\partial T_{ijt}}\frac{T_{ijt}}{X_{ijt}} = (1-\epsilon)\frac{T_{ij}}{w_i\tau_{ij}+T_{ij}} \equiv \alpha \tag{14}$$

This elasticity is equivalent to the estimated elasticity of trade with respect to freight rates above, α (equation (13)). In order to obtain trade elasticity with respect to price (ϵ), 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 per-

[33]The January 2009 results intuitively has more power in the form of a higher first state F-stat compared to the baseline since it closer to and more correlated with the start of my data period.

cent of the median price.[34] The trade elasticity ϵ calculated from equation (14) is 20.96.

The trade elasticity estimated in this paper is short-run elasticity, at the monthly and port level, for containerized trade which takes into account endogeneity concerns between trade and trade cost. This elasticity differs from the estimates in the general trade literature (which are typically smaller in magnitude) in three main ways which are described below. Following this, I show that both my weight and value per weight estimates using the same empirical specification (Table 4) are well within the range of what previous studies have found. Lastly, I introduce a simple model that illustrates the two sources of bias in this paper, simultaneous equation bias and bias induced by the round trip effect, and show that they contribute to a larger difference between the OLS and IV estimates. I then solve for the implied supply elasticity using my IV and OLS estimates and show that it is in the ballpark of available supply elasticities in the literature.

Trade costs are generally modelled as exogenous. While there are recent exceptions, trade elasticity estimates typically do not take into account the reverse causality of trade cost with respect to trade flows. In fact, the OLS estimates in this paper imply a trade elasticity of 4.7 that is very much in line with the literature (Column (2), Table 4). When taking into account the endogeneity between transport cost and trade flows, the IV estimates here imply a four- to five-fold increase from the OLS estimates. This increase in magnitude is in line with previous literature which has taken into account the endogeneity of trade costs. Specifically, Baier and Bergstrand (2007) finds a similar five-fold increase in the effect of free trade agreements (FTAs) on trade flows after taking into account the endogeneity of FTAs. Trefler (1993) finds an even 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.

Typical estimates are usually at the country-level and for all products. In order to effectively control for multilateral resistance terms in this paper to eliminate any importer- and exporter-specific sources of selection bias (Limão, 2016), I conduct my analysis at the US-port-and-foreign-country level. As such, potential substitution across US ports

[34]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) and so it is assumed here that transport cost make up most of the per unit trade cost.

(LA/LB, NY, and Houston) could account for the elasticity in this paper being larger than what is typically found in the literature. If the freight rates out of the Houston port increases, for example, an exporter could choose to export out of the New York port instead. Typically these elasticities are estimated at the country level and these margins of substitution would not apply. As a result, even when I aggregate my trade elasticity to the annual level (as seen in the next point below), its magnitude is still larger than what is typically found in the literature due to the potential for port-level substitutions. This is echoed in Asturias (2020) who finds an elasticity of substitution across port-pairs of 13.9 using cross section data from 10 US ports to 300 foreign destinations, which is much higher than typical country-level elasticities of substitution.

Additionally, the trade elasticity estimated in this paper is for containerized goods. Since the majority of manufacturing good is containerized (Korinek, 2008), this elasticity is more comparable to a product-level elasticity for manufacturing. Shapiro (2015)'s 6-month manufacturing trade elasticity of 7 is within one standard error of my 6-month trade elasticity (calculated from column (3), table 6). My annual trade elasticity of 12.6 (calculated from column (4), table 6) is within the range of 3.6-12.86 estimated by Eaton and Kortum (2002) and is lower than the 51-69 range by Caliendo and Parro (2014).

Trade elasticity estimates are usually longer-run, focused on one year or more. Since my product-level trade elasticity is at the monthly level, the magnitude of my 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. For example, a car manufacturer would be able to substitute its demand for imported tires from August to September, but it unlikely to be able to substitute from using tires at all for 6 months or a year. The ability of importers and exporters to substitute is easier over a shorter time period compared to a longer period.

My results reflect this: aggregating my monthly estimation upwards decreases its magnitude (Table 6) My elasticity decreased by almost half (45%) between the monthly and annually time periods, which decreases my trade elasticity to 12.6 (calculated from columns (1) and (4), Table 6) although it is acknowledged the standard errors are relatively large at higher aggregations. This decrease in elasticity as time period aggregation increases is also found in other studies. Shapiro (2015) finds that his elasticity is almost halved when aggregating from the bi-annual-level to the annual-level while Steinwender (2018) also sees a substantial decrease in her daily demand elasticity when aggregating up to 3 months.[35]

Furthermore, while there isn't a direct comparison of the trade elasticities in this paper to the literature, I show that both my weight and value per weight elasticity with respect to freight rates estimates are well within the range of what previous studies have found. My OLS weight estimates of -0.8 to -1.1 (Table 4) are within the range of previously established OLS volume elasticities for other transport modes in the transport literature (De Palma et al., 2011; Oum, Waters and Yong, 1992): -0.8 to -1.6 (air), -0.7 to -1.1 (truck), and -0.4 to -1.2 (rail). In addition, my value per weight IV estimates of 0.84 to 1.1 are squarely within the estimates from Hummels and Skiba (2004) who find a price elasticity with respect to freight cost between 0.8 to 1.41.

Last but not least, I introduce a simple model incorporating the two sources of bias in this paper and show that implied supply elasticity is in the ballpark of existing estimates in the literature (see Appendix A.5 for further details). There are two sources of bias here: (1) simultaneous equation bias since the supply and demand for transport services on a particular route ij is simultaneously determined, and (2) bias induced by the round trip effect where transport supply for routes ij and ji are jointly determined, leading to a negative relationship between the transport prices on route ij and ji. Both these sources of bias contribute to larger magnitude differences between the OLS and IV estimates in my results, as predicted in Table 4. After calibrating and solving for the supply elasticity implied by this model, I show that my estimate of about 0.78 is in the ballpark of Broda, Limao and Weinstein (2008) who estimates a median elasticity of supply of 0.6 across 15 importers annually over the period 1994-2003.

6 Counterfactual Implications for Trade Policy

In order to evaluate the implications of the round trip effect effect for trade policy, I simulate two counterfactual import tariff changes in a quantitative Armington trade model

[35] The trade elasticity in this paper is very different from trade elasticities estimated from aggregate trade flows (Ruhl, 2008; Boehm, Levchenko and Pandalai-Nayar, 2020), where substitution margins are operative in longer runs due to firm entry or switching of suppliers. As a result, the aggregate trade elasticities in those papers are larger in the long-run relative to the short-run.

utilizing my estimated trade elasticities and theory framework. The first counterfactual doubles US import tariffs on all trading partners from its 2014 average of 1.33 percent while the second counterfactual simulates the impact of the Trump administration's Section 301 tariffs on China. I first describe the calibration and estimation process below and then present my counterfactual results.

6.1 Taking the Model to Data

I use tariff rates (τ_{ij}) from the trade-weighted effectively applied tariff rates for manufactures from the World Bank. Manufacturing import tariffs are chosen since the majority of manufactured products are transported via containers (Korinek, 2008). The round trip marginal cost for each port pair is the sum of the freight rates going both ways ($c_{\overleftrightarrow{ij}}$, equation (4)). Input prices (w_i) are approximated by hourly manufacturing wages from the OECD following Eaton and Kortum (2002). The availability of OECD wages limits the countries in this analysis. Specifically, the lack of comparable manufacturing wages excludes Asian countries like Hong Kong and India. To include China, I approximate its manufacturing wages from US OECD manufacturing wages using the harmonized minimum wage ratio (0.3) between China and US from the International Labor Organization.[36]

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 as well as the profits of the transport firms (equations (2) and (3) respectively in the theory section):

$$p_{ij} = w_i \tau_{ij} + T_{ij}/l_{ij}$$
$$\pi_{i,j} = T_{ij} l_{ij} Q_{ij} + T_{ji} l_{ji} Q_{ji} - c_{\overleftrightarrow{ij}} \max\{l_{ij}Q_{ij}, l_{ji}Q_{ji}\}$$

[36] The UK and US International Labor Organization harmonized minimum wage ratio is the same as their OECD wage ratio (1.02), which serves a basis for this approximation.

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 (4) and (5)):

$$\begin{aligned} T^*_{ij} &= \frac{1}{1+Y_{ij}}\left[c_{\overleftrightarrow{ij}} + l_{ji}w_j\tau_{ji} - Y_{ij}l_{ij}w_i\tau_{ij}\right] \\ X^*_{ij} = p_{ij}Q_{ij} &= \left[\frac{\epsilon}{\epsilon-1}\frac{1}{a_{ij}}\right]^{-\epsilon}\left[\frac{1}{1+Y_{ij}}\left(w_i\tau_{ij} + \frac{1}{l_{ij}}\left(c_{\overleftrightarrow{ij}} + l_{ji}w_j\tau_{ji}\right)\right)\right]^{1-\epsilon}, \\ \text{where } Y_{ij} &= \frac{a_{ji}}{a_{ij}}\left(\frac{l_{ji}}{l_{ij}}\right)^{1+1/\epsilon} \end{aligned} \tag{15}$$

I am able to match the observed freight rates and trade value data exactly because my model is just identified. Since the results below are based on 2014 data, I construct an out of sample model fit instead for 2015 trade value and freight rates using my estimated parameters. Between my estimated values and the observed 2015 data, I fit the out of sample data well with high correlations of 0.71 for trade value and 0.74 for freight rates (Figure A.7).

6.2 Counterfactual: Doubling US import tariffs

Table 8 shows the trade predictions from doubling US import tariffs on its trading partners. The initial trade-weighted average is 1.33 percent. The first two rows, labeled as "Round Trip", show the predicted percent changes in import and export freight rates, trade value, and overall trade balance for the 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 8 echoes the predictions from Proposition 1. The round trip model predicts that US import freight rates will fall by 0.12 percent to mitigate the US tariff increase. Even though import freight rates are now smaller, US import value decreases overall by 1.14 percent (as predicted by Lemma 1). The model with exogenous transport cost predicts a larger decrease in import value (2.35 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 0.19 percent while US export value decreases by 1.71 percent.[37] The exogenous transport cost model predicts no changes on the export side.

Table 8: Trade Predictions from Doubling US Import Tariff

Model		Freight Rate	Trade Value	Trade Balance (Exports/Imports)
Round Trip	Import	-0.12%	-1.14%	- 0.57%
	Export	+0.19%	-1.71%	
Exogenous	Import	0	-2.35%	+ 2.41%
	Export	0	0	

Notes: Freight rate changes are average percent changes across 26 routes while trade value and imbalance changes are total percent changes. Import tariffs are the 2014 trade-weighted effectively applied tariff rates for manufactures. Average US import tariff is 1.33 percent with the minimum being 0.09 percent (Australia) and the maximum being 2.69 percent (China). Domestic input prices are approximated by hourly OECD manufacturing wages and ILO harmonized wages.
Source: Author's calculations using Census Bureau, Drewry, International Labor Organization (ILO), OECD, and WITS. ■

From comparing both models, three main observations can be made. First, the exogenous transport cost model predicts no changes in freight rates when US manufacturing 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 exports while the round trip model shows a fall in export value as a result of higher export costs. Third, the exogenous model predicts a larger fall in import trade value relative to the round trip model—by about 35 percent. This over-prediction is robust to using other trade elasticity estimates as well. With the trade elasticity of 5 as suggested by Head and Mayer (2014), the exogenous model over-predicts the average import value increase by a very similar amount, 34.6 percent. Last but not least, the exogenous model's trade balance (ratio of exports to imports) is predicted to improve while the round trip trade balance deteriorates.

The over-prediction of the fall in imports or mitigation effects between the exogenous

[37]The estimates in Hayakawa, Ishikawa and Tarui (2020) from doubling their tariff rates are approximately 6-7 times larger than these results. One reason for this discrepancy, other than differences in empirical methodology, is the differences in our samples. The US has a low average tariff rate of 1.33 percent while their sample, which includes many developing countries, has a much higher average tariff rate of 6 percent.

and round trip model, are large and robust to using different trade elasticity estimates. This is because the trade elasticity adjusts the imports' response to tariffs proportionally, with and without the endogenous round trip adjustment. I confirm this by showing a high correlation of 0.9 of between the route-level mitigation effects using both elasticities (Figure A.9). I also show analytically that this is true particularly for smaller ranges of tariff changes. Lastly, I show that the factors driving the mitigation effects are the unit-adjusted relative preferences for routes. A higher unit-adjusted relative preference for route ij means that consumers have a higher preference for ij goods compared to ji goods. This means that an increase in j's import tariffs on i will result in a smaller import flows decrease due to this high relative preference. As a result, the mitigation impact from the round trip effect for route ij will be smaller. I confirm that this is the case by showing a highly positive correlation of 0.96 between the route-level unit-adjusted relative preferences against its mitigation effects. I further elaborate on the model and data features that drive these result in Appendix Section A.6.

These differences in trade predictions have important policy implications. If a country chooses to pursue protectionist policies by increasing their import tariffs and they estimate their trade outcomes using a model with exogenous transport costs, they will over-predict the level of protection they are affording their local industries—the fall in imports from their trading partners—and predict no other direct impact on their exports and transport costs. As a result, the exogenous model will predict an improvement in the country's overall trade balance with its partners. However, a model which endogenizes transport costs with respect to the round trip effect will paint a very different picture: while the country's imports fall, so will its exports. The combination of the exports decrease (due to the spillover effect) and the smaller mitigated imports decrease results in the opposite intended effect: a worsening of the country's trade balance.

In order to estimate 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 (A.4) 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 0.1 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 is 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 are 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 (15)).

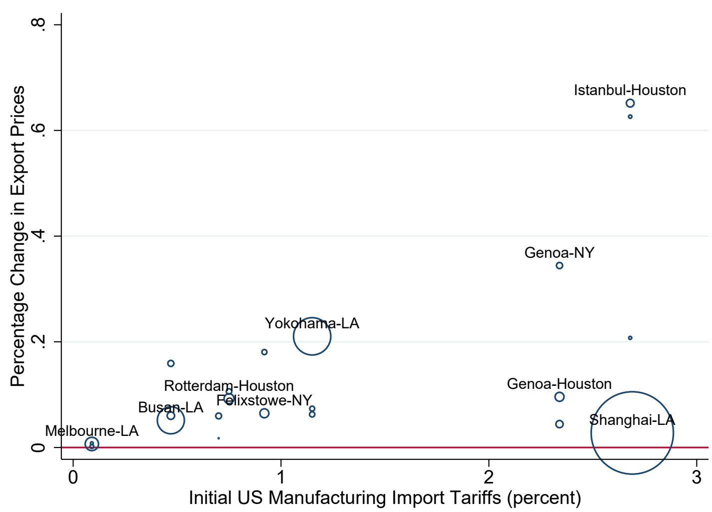

Figure 6: Port-level export price increases from doubling US import tariffs

Notes: Circles denote trade share of route. Red line denotes no change in export prices which is predicted if transport costs are exogenous. Trade-weighted effectively applied tariff rates are used.
Sources: WITS, OECD, Drewry, Census Bureau, and author's calculations. ■

6.3 Counterfactual: US Section 301 tariffs on China

In 2018, the Trump administration started a series of sharp import tariff increases on its major trading partners. China was particularly targeted. These tariffs were authorized after a trade investigation was conducted under Section 301 of the Trade Act of 1974. By February 2020, the US trade-weighted average tariff rates on China is 19.3% (Bown, 2020).

I simulate the results from this increase in US import tariffs on China (Table 9). Here the relative gap between the average freight rate changes are much larger (0.08 percent decrease in imports freight rates compared to 0.25 percent increase in export freight rates). This is due to the high unit-adjusted relative preferences for China-US routes which reduces the mitigation effect on import freight rates and also import flows. On the exports side, the opposite direction routes (US-China) has a low unit-adjusted relative preference which translates into larger spillover effects in terms of export freight rates and export flows. As a result, the US-China trade balance will worsen by 0.1%.

Table 9: Trade Predictions from US Section 301 tariffs on China

Model		Freight Rate	Trade Value	Trade Balance (Exports/Imports)
Round Trip	Import	-0.08%	-3.56%	- 0.11%
	Export	+0.25%	-3.67%	
Exogenous	Import	0	-5.02%	+ 5.28%
	Export	0	0	

Notes: Freight rate changes are average percent changes across 3 US-China routes while trade value and imbalance changes are total percent changes. The trade-weighted average US Section 301 import tariffs on China on February 2020 is 19.3% Bown (2020). Domestic input prices are approximated by hourly OECD manufacturing wages and ILO harmonized wages.
Source: Author's calculations using Census Bureau, Drewry, International Labor Organization (ILO), OECD, (Bown, 2020), and WITS. ■

Relative to the round trip model, the exogenous transport cost model over-predicts the imports decrease and does not predict any export changes (as well as no freight rate changes). This results in the exogenous model predicting a trade balance improvement of about 5 percent for the United States while the round trip model finds the opposite—a worsening of the trade balance. The mitigation effects from the imports fall across both models is 29%, which is again roughly similar using a trade elasticity of 5 (32.6%).

7 Conclusion

This paper provides a microfoundation for transport costs by incorporating the round trip effect, an optimal strategy due to cost considerations employed by various transport carriers including containerships, cargo airlines, and trucks. The first contribution of this paper is to identify the round trip effect empirically. The main implication of the round trip effect is the negative correlation in freight rates within port pairs. This paper is the first to provide systematic evidence for this negative correlation. To address the endogeneity between freight rates and trade flows, I construct a novel IV using the round trip insight to establish the impact of the round trip effect on freight rates—a exogenous negative shock to trade from i to j induces a positive increase in freight rates from j to i.

The second contribution of this paper is to estimate a trade elasticity with respect to transport price for containerized products. 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.

The third contribution simulates counterfactual import tariff changes in a quantitative model in order to evaluate the implications of this effect for trade policy. I show that the counterfactual tariff increases does not just decrease US imports to its trading partners, but also decrease US exports to the same partners. A trade model with exogenous transport costs would over-predict the import decrease by 30-35 percent relative to the round trip model, not predict any associated bilateral export decrease at all This results in the exogenous model predicting a trade balance improvement from protectionist policies while the round trip model shows the opposite: a worsening of the trade balance

It is acknowledged here that the assumption of exogenous iceberg trade costs, often to be symmetric, is not an assumption that trade economists ever argued to be realistic. Instead, this assumption is made for tractability. So under what conditions is it essential to incorporate the insights from this paper? First, the round trip effect would be important to incorporate when one is estimating trade costs for routes with high mitigation effects (figure A.10). These are routes with low unit-adjusted relative preferences and ones where the predicted trade difference between the round trip and exogenous model would be the largest. Examples of these routes are like Felixstowe-LA and Genoa-Houston. Generally speaking, these routes have relatively similar ratios of exports and imports along with export and import freight rates.

Second, the round trip effect would be important to incorporate on big routes, where ships are more likely to go back and forth from hub ports to hub ports in fixed routes. Ganapati, Wong and Ziv (2020) finds evidence that the global container shipping takes place on a hub-and-spoke network with bigger countries or hubs tending to ship more directly to the US, with less stops along the way—meaning that they are more likely to be subjected to the round trip effect.

Third, when studying goods that are shipped over transportation modes that are subject to the round trip effect. These include goods transported in containers, trucks, and air cargo. Examples of goods that are not shipped via round trips are like grains and coal, which are shipped in bulk liner ships, or oil, which is shipped in oil tankers. These bulk liner and tanker ships are likely to depart from their destinations without cargo and therefore have to search for their next load, like taxis, while containerships have fixed publicized schedules since they are able to pick up a wide variety of cargo at each stop like buses (Brancaccio, Kalouptsidi and Papageorgiou, 2020).

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A Appendix

A.1 Tables and Figures

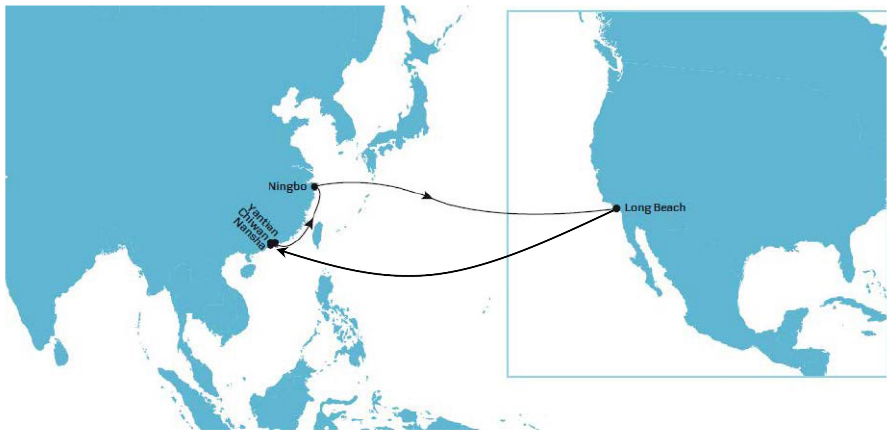


Figure A.1: Example of the round trip effect: Containership route between US and China
Notes: Land is shaded blue. The containership departs from Yantian on a Tuesday, Ningbo on a Thursday two days later, and arrives in Long Beach the following Wednesday after 12 days. Two days later (Friday), it departs from Long Beach and return to Ningbo and Yantian on the westbound service. This announcement of exact arrival/departure days for each port is commonly done by other containership companies as well.
Source: Maersk East-West Network, TP3 Service. ■

Table A.1: Regression of container freight rates within port-pairs

	(1) ln Freight Rates	(2) ln Freight Rates	(3) ln Freight Rates	(4) ln Freight Rates
ln Opposite Dir FR	-0.191	-0.846	-0.841	-0.851
	(0.0846)	(0.0194)	(0.0290)	(0.0263)
ln Distance	0.629			
	(0.0874)			
Observations	3210	3210	1695	1515
Route FE		Y	Y	Y
Time FE	Y	Y	Y	Y
Routes			Balanced	Imbalanced
R^2	0.213	0.850	0.830	0.870
F	26.13	1895.2	838.7	1042.8

Notes: Robust standard errors in parentheses are clustered by route. All variables are in logs. Column (1) has distance and time controls, Column (2) has route and time controls, Column (3) is restricted to only the second and third quartiles of the US trade imbalance distribution from year 2003 (more "Balanced" routes), and Column (4) is restricted to only the top and bottom quartiles of the US trade imbalance distribution from year 2003 (more "Imbalanced" routes).
Source: Drewry, sea-distance.org, and author's calculations. ■

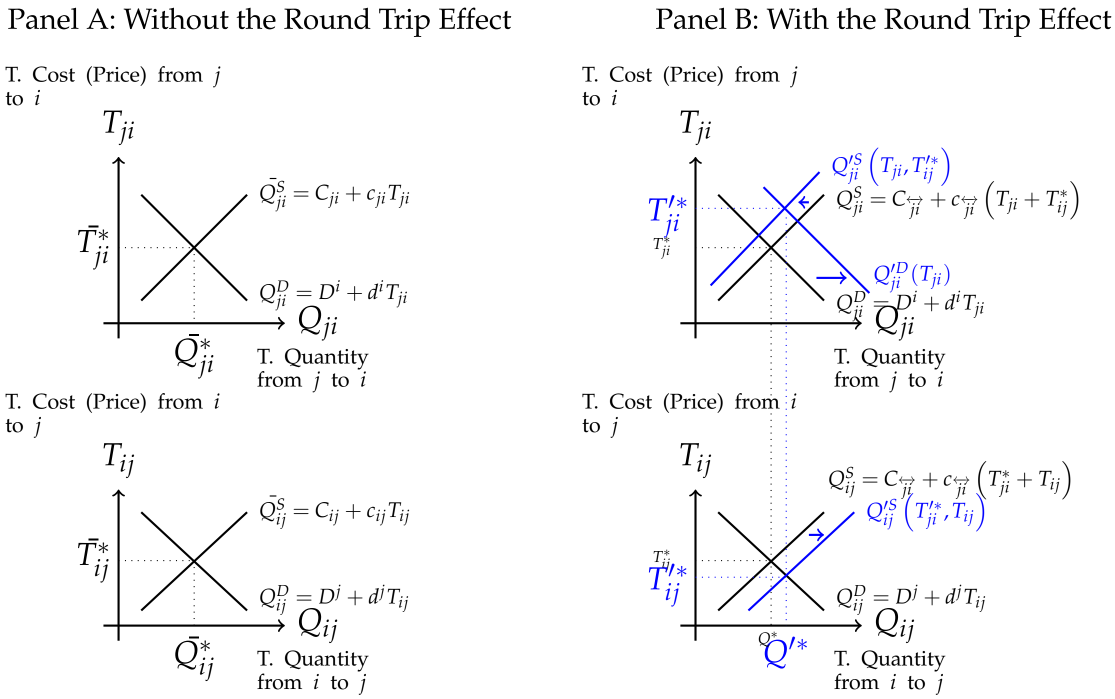


Figure A.2: Transport markets between countries i and j in the absence (Panel A) and presence (Panel B) of the round trip effect

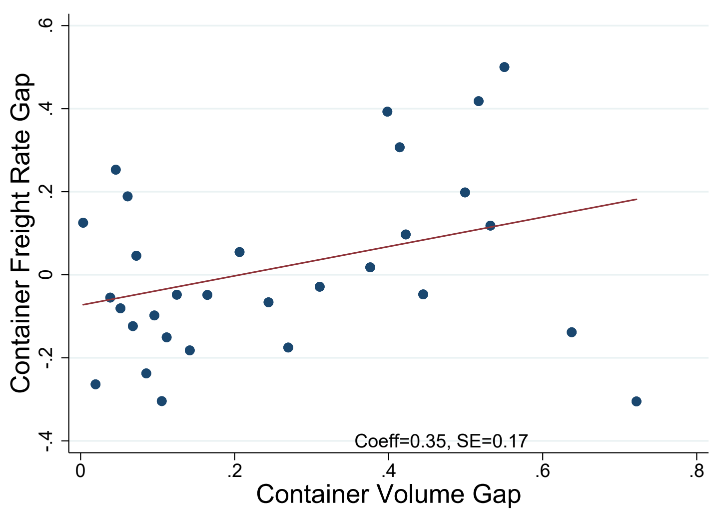


Figure A.3: Positive correlation between container volume and freight rate gaps

Notes: The gap variables are the normalized difference between the higher and lower volume directions. Sources: Drewry, Census Bureau, and author's calculations. ∎

Panel A: Containerized Trade Value

Panel B: Containerized Trade Weight

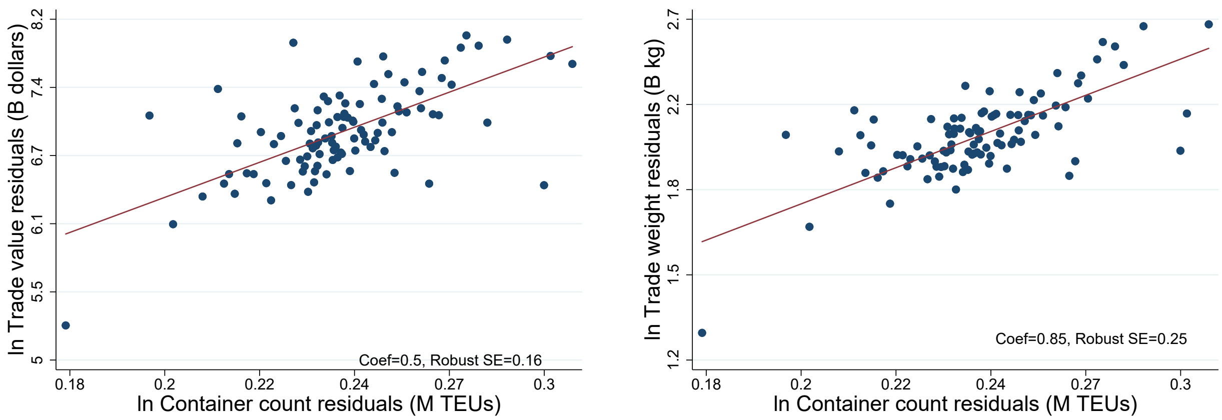
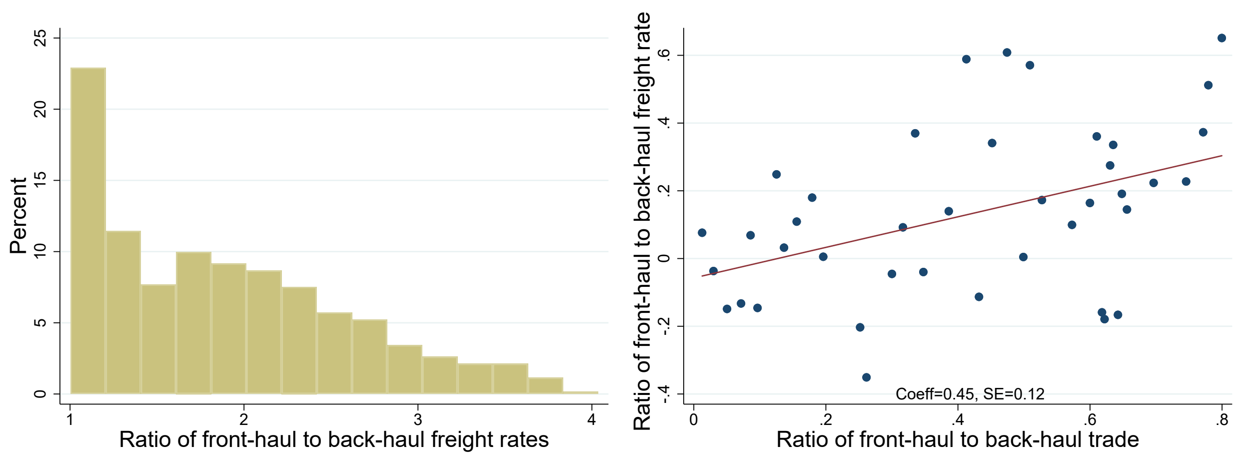


Figure A.4: Containerized trade value and weight (X_{ijt}) are positively correlated with container volume (Q_{jit}) within routes



Panel (A)

Panel (B)

Figure A.5: (A) Distribution of transport cost gaps and (B) Positive correlation between trade value and transport cost gaps

Notes: Ratios are calculated as the normalized difference between the higher (front-haul) and lower (back-haul) values for each origin-destination pair. Panel (A) is at the port-pair level while Panel (B) is at the country level

Sources: Drewry, Census Bureau, and author's calculations. ■

Table A.2: Regression of freight rates on trade

	(1) ln Freight Rate	(2) ln Freight Rate	(3) ln Freight Rate
ln Value	-0.0881		
	(0.0230)		
ln Weight		-0.123	
		(0.0178)	
ln Value/Wgt			0.175
			(0.0420)
Observations	5684	5684	5684
R^2	0.521	0.558	0.524
F	14.74	48.02	17.31

Notes: Robust standard errors clustered by route in parentheses. Time and dyad level fixed effects are included for each regression.
Source: Drewry, Census Bureau, and author's calculations. ■

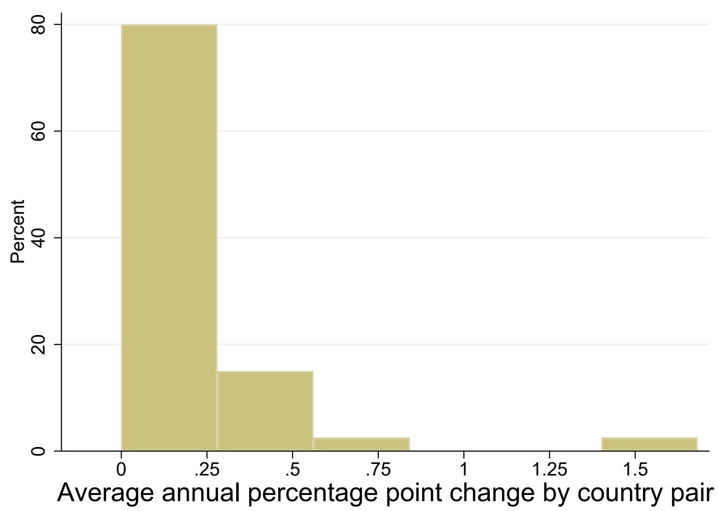


Figure A.6: Distribution of tariff rates during the sample period
Notes: Average change is 0.18 percentage points (sd 0.29). Effectively applied average tariff rates for manufactures (average tariff is 4.2%, sd 3%).
Source: World Bank WITS, and author's calculations. ■

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

	(1) ln Freight Rate	(2) ln Freight Rate
ln Opp Dir Predicted Trade Value	0.0406	0.0370
	(0.0115)	(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

Notes: Robust standard errors in parentheses are clustered by route. Results are robust to clustering at the route and product, dyad (two-way route), and dyad with products level. 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. Second stage results are in Table 4.
Sources: Drewry, Census Bureau, and author's calculations. ■

Table A.4: First-Stage Regressions of Containerized Trade Demand Estimates for All Countries without Fragmented Products (table 5)

	(1) ln Freight Rate	(2) ln Freight Rate
ln Opp Dir Predicted Trade Value	0.0144	0.0143
	(0.00740)	(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

Notes: Robust standard errors in parentheses are clustered by route. 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, Census Bureau, and author's calculations. ■

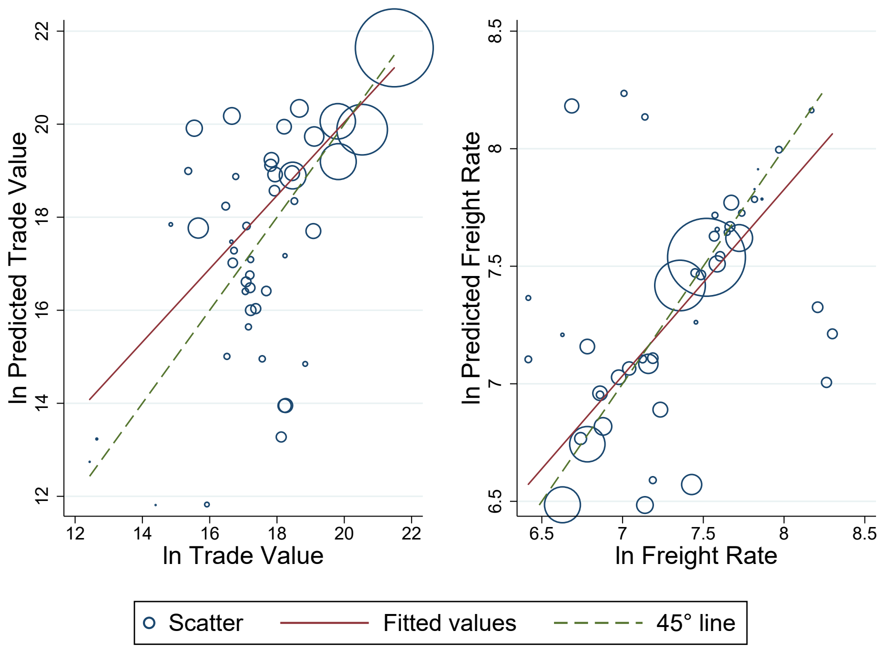


Figure A.7: Out of Sample Fit

Notes: Year 2014 parameter estimates are used to predict and fit year 2015 trade value (Panel (A)) and freight rates (Panel (B)) data.

Source: Authors' calculations using Census Bureau, Drewry, OECD, and World Bank WITS data. ■

A.2 Data Appendix

This section provides more information on the data sets in this paper as well as the use of spot market rates.

A.2.1 Container freight rates and trade data

Container freight rates data. 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 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 (Auckland), 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)

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.

Containerized trade data. The data on containerized trade is from the Census Bureau, 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.

Matched data set. 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 aggregate my freight rates data set to the US port and foreign country level to match the containerized trade data. This results in 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). All data 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).

When matching between port-level freight rates to port-country level trade data, there is the potential for measurement errors. However, due to the presence of scale economies in shipping, most countries have one major container port where most of their goods are shipped through. This applies to the majority of non-US ports in my dataset which means that generally the port-level freight rates are representative of the rates faced by the country. The only exception is very large countries with multiple big ports. In my dataset, this applies to only one country—China. In my data, there are 3 Chinese ports which handles more than 1 million containers annually so I chose the longest available time series to approximate for US-China trade. In cases where the dataset only covers one port for a region (like Africa—where there is only South Africa's port Durban), my estimate could potentially be a lower bound to the extent that neighboring countries' containers are transported to South Africa and then traded to the US through South Africa.

A.2.2 Use of spot market rates

This paper uses a data set on spot market freight rates. There are two main reasons for this: (1) data availability and (2) a variety of linkages between spot and contract rates during the period of this data set.

In the past, price-fixing agreements among carriers (known as conference agreements) on global shipping routes were successfully enforced because conference members are required to file their contract rates with the FMC and these rates were publicly available (Clyde and Reitzes, 1995). In recent years, however, the FMC has introduced several pro-competitive regulations to curtail the conferences' enforcement abilities: 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. Today, conference members are able to deviate privately from conference rates without repercussion. Unfortunately, the same regulations also enforce that these contract rates are off-limits to researchers. My FOIA request with the FMC on April 2015 for container contracts was rejected on the grounds that the information I seek is prohibited from disclosure by the Shipping Act, 46 U.S.C. §40502(b)(1).[1]

Additionally, there has been a period of persistent over-capacity in the container shipping industry which overlaps with my data period—2011 to 2016. The 2008 recession resulted in an idling of the existing shipping fleet, at the same time that another 70 percent of that fleet was still scheduled for delivery by 2012 (Kalouptsidi, 2014). The recession and the time to build lags contributed to a persistent over-capacity in the container shipping industry, up to as much as 30 percent more space on ships than cargo, which contributed to the 2016 bankruptcy of the world's seventh-largest container shipping line (South Korea's Hanjin Shipping, The Wall Street Journal). At the same time, a number of strategies were implemented in the container shipping industry in order to smooth volatility. These include negotiations of shorter-term contracts and cargo splitting between both rates,[2]

[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.

[2] Conversation with Roy J. Pearson, Director, Office of Economics & Competition Analysis at the Federal

indexing of contract rates to spot rates (Journal of Commerce, 2014), and introduction of hybrid contracts to allow for easy switching to spot rates (Journal of Commerce, 2016).

A.2.3 Hub and spoke networks and transshipment

In this section, I explain how the presence of hub and spoke networks as well as transshipment affects the results in this paper.

Hub and spoke networks. The presence of this mechanism would mean that my result in Stylized Fact 2 can potentially be a lower bound estimate. I illustrate with an example: say Singapore is the hub, the Philippines is the spoke, and without loss of generality assume that Singapore exports more to the Los Angeles (LA) than the other way around (if trade were balanced then the estimates would be much less affected). Through the hub and spoke network, goods that LA is exporting to the Philippines would constitute a relatively higher share of the cargo on a ship going from LA to Singapore. This means that any shocks to LA-Singapore trade would be less correlated with Singapore-LA freight rates since they make up a smaller cargo share of the transport supply. The presence of this mechanism would weaken the correlation that I am finding in my Stylized Fact 2 which means that my current significantly positive estimate is a lower bound.

Transshipment. Similar to the explanation above, the presence of this mechanism could also potentially result in the correlation in Stylized Fact 2 being a lower bound estimate. To adopt the example above, Filipino exports to the LA would be transshipped in Singapore before being transported to the LA and LA exports to the Philippines would be transshipped in Singapore before its ultimate destination in the Philippines.

A.3 Baseline Model Theory Appendix

A.3.1 Model with exogenous transport cost

In the exogenous transport cost model, the cost of transport is the exogenously determined one-way marginal cost of shipping (c_{ij}). The delivered price of country i's good in j (p_{ij}^{Exo}) is as follows:

$$p_{ij}^{Exo} = w_i \tau_{ij} + c_{ij} \tag{A.1}$$

Maritime Commission, January 2015.

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.[3] 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:

$$\begin{aligned} q_{ij}^{Exo} &= \left[\frac{\epsilon}{\epsilon-1}\frac{1}{a_{ij}}\left(w_i\tau_{ij}+c_{ij}\right)\right]^{-\epsilon} \\ X_{ij}^{Exo} \equiv p_{ij}^{Exo}q_{ij}^{Exo} &= \left[\frac{\epsilon}{\epsilon-1}\frac{1}{a_{ij}}\right]^{-\epsilon}\left[\left(w_i\tau_{ij}+c_{ij}\right)\right]^{1-\epsilon} \end{aligned} \tag{A.2}$$

A.3.2 Model with endogenous transport cost & round trip effect: Equilibrium

The utility-maximizing quantity of i's good consumed in j (q_{ij}) 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:[4] $q_{ij} = \left[\frac{\epsilon}{\epsilon-1}\frac{1}{a_{ij}}\left(T_{ij}\right)\right]^{-\epsilon}$ where an increase in j's preference for i's good (a_{ij}) will increase the equilibrium quantity. On the other hand, an increase in i's wages, j's import tariff on i, and the transport cost will decrease it.

The equilibrium freight rate for route ji is

$$T_{ji}^{R} = \frac{1}{1+A_{ji}}\left(w_i\tau_{ij}+c_{\overleftrightarrow{ij}}\right) - \frac{1}{1+A_{ji}^{-1}}\left(w_j\tau_{ji}\right), \ A_{ji} = \frac{a_{ij}}{a_{ji}} \tag{A.3}$$

[3] From equation (A.2), ϵ is the price elasticity of demand: $\frac{\partial q_{ij}^{Exo}}{\partial p_{ij}^{Exo}}\frac{q_{ij}^{Exo}}{p_{ij}^{Exo}} = -\epsilon$. 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.

[4] From equation (A.2), ϵ is the price elasticity of demand: $\frac{\partial q_{ij}^{Exo}}{\partial p_{ij}^{Exo}}\frac{q_{ij}^{Exo}}{p_{ij}^{Exo}} = -\epsilon$. 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.

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

$$
\begin{aligned}
p_{ji}^{R} &= \frac{1}{1+A_{ji}}\left(w_i\tau_{ij} + w_j\tau_{ji} + c_{\overleftrightarrow{ij}}\right) \\
q_{ji}^{R} &= \left[\frac{\epsilon}{\epsilon-1}\frac{1}{a_{ji}}\frac{1}{1+A_{ji}}\left(w_i\tau_{ij} + w_j\tau_{ji} + c_{\overleftrightarrow{ij}}\right)\right]^{-\epsilon} \\
X_{ji}^{R} &= \left[\frac{\epsilon}{\epsilon-1}\frac{1}{a_{ji}}\right]^{-\epsilon}\left[\frac{1}{1+A_{ji}}\left(w_i\tau_{ij} + w_j\tau_{ji} + c_{\overleftrightarrow{ij}}\right)\right]^{1-\epsilon} \\
&\text{where } A_{ji} = \frac{a_{ij}}{a_{ji}}
\end{aligned}
\tag{A.4}
$$

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: $T_{ij}^{Sym} = T_{ji}^{Sym} = \frac{1}{2}c_{\overleftrightarrow{ij}}$. 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:

$$
\begin{aligned}
p_{ij}^{Sym} = p_{ji}^{Sym} &= \frac{1}{2}\left(w_j\tau_{ji} + w_i\tau_{ij} + c_{\overleftrightarrow{ij}}\right) \\
q_{ij}^{Sym} = q_{ji}^{Sym} &= \left[\frac{\epsilon}{\epsilon-1}\frac{1}{a}\frac{1}{2}\left(w_j\tau_{ji} + w_i\tau_{ij} + c_{\overleftrightarrow{ij}}\right)\right]^{-\epsilon} \\
X_{ij}^{Sym} = X_{ji}^{Sym} &= \left[\frac{\epsilon}{\epsilon-1}\frac{1}{a}\right]^{-\epsilon}\left[\frac{1}{2}\left(w_j\tau_{ji} + w_i\tau_{ij} + c_{\overleftrightarrow{ij}}\right)\right]^{1-\epsilon}
\end{aligned}
\tag{A.5}
$$

A.3.3 Comparative statics with preference changes

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 (A.1)). 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 (8)). This import increase is less than the import increase in the exogenous model. The following lemma can be shown:[5]

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*

[5] See Theory Appendix for proof.

quantity and value from i will increase while leaving its import price from i unchanged.

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

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.

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

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.

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

A.4 The Round Trip Effect with Imperfect Competition

This section presents the theoretical implications of endogenous transport costs and the round trip effect in the baseline Armington trade model when the transport firm is imperfectly competitive—a monopoly. The setup of the model is skipped here since it is the same as the baseline model. Under imperfect competition, the mitigation and spillover impacts could be larger or smaller relative to the perfect competition, depending on whether the demand specification pass-through is greater or less than one. Below I first show the profit function for the round trip monopolist transport firm, then I solve for the equilibrium outcomes under both demand specifications.

A.4.1 The round trip effect and monopolist transport firm

The profit function of a monopolistic transport firm servicing the round trip between i and j ($\pi^{M}_{\overset{\leftrightarrow}{ij}}$) is as below:

$$\pi^{M}_{\overset{\leftrightarrow}{ij}} = T_{ij}\left(q_{ij}\right) q_{ij} + T_{ji}\left(q_{ji}\right) q_{ji} - c_{\overset{\leftrightarrow}{ij}} \max\{q_{ij}, q_{ji}\} \tag{A.6}$$

where all the notations follow from the model in the main theory model with the exception here that the supply of the monopolist transport firm affects the transport price along each route, $T_{ij}(q_{ij})$ and $T_{ji}(q_{ji})$.

A profit-maximizing transport monopolist (equation (A.6)) will produce where the marginal revenue (MR) of both its products—transport services from i to j and the return—equals the marginal cost of a round trip service between i and j $c_{\overleftrightarrow{ij}}$:

$$\underbrace{T'_{ij}\left(q_{ij}\right)q_{ij}+T_{ij}\left(q_{ij}\right)}_{\text{MR from shipping } i \text{ to } j}+\underbrace{T'_{ji}\left(q_{ji}\right)q_{ji}+T_{ji}\left(q_{ji}\right)}_{\text{MR from shipping } j \text{ to } i}=c_{\overleftrightarrow{ij}} \tag{A.7}$$

Since the demand for transport services is downward sloping, $T'_{ij}\left(q_{ij}\right)<0$ and $T'_{ji}\left(q_{ji}\right)<0$. The initial negative correlation of the freight rates between i and j with each other still holds, conditional on the round trip marginal cost $c_{\overleftrightarrow{ij}}$ as well as the demand responsiveness in both countries (price elasticity of demand, wages, and tariffs).

A.4.2 Demand pass-through greater than one

The utility function used in the theory section has a constant elasticity of demand (equation (1)) which has a pass-through of greater than one. Below I show the equilibrium results from this class of demand functions. Both the other two optimality conditions from equations (5) and (6) hold here.

Similar to the earlier model, the interior solution is assumed here where demand is symmetric enough in both directions such that the transport market is able to clear at positive freight rates both ways and the quantity of transport services are balanced between the countries. The equilibrium freight rate for route ij under the round trip effect (T^M_{ij}) when the transport firm is a monopolist can be derived from the market clearing condition for transport services:

$$T^M_{ij}=\frac{1}{1+A_{ij}}\frac{\sigma}{\sigma-1}c_{\overleftrightarrow{ij}}-\frac{1}{1+A^{-1}_{ij}}\left(A-\frac{1}{\sigma-1}\right)(w_i\tau_{ij})+\frac{1}{1+A_{ij}}\frac{\sigma}{\sigma-1}(w_j\tau_{ji}),\ \ A_{ij}=\frac{a_{ji}}{a_{ij}} \tag{A.8}$$

where A_{ij} is the ratio of preference parameters between i and j. The monopolist freight rate for route ij is a function of the same terms as the perfect competition rates: increasing in the marginal cost of servicing the round trip route, decreasing with the destination country j's import tariff on i (τ_{ij}) and origin i's wages (w_i), as well as increasing in the origin country i's import tariff on j (τ_{ji}), as well as destination j's wages (w_j). Since $\frac{\sigma}{\sigma-1} > 1$ and $\frac{1}{\sigma-1} > 0$, it can be directly calculated that the is higher than the rates under perfect competition.

The new equilibrium price of country i's good in j is still increasing in the marginal cost of round trip transport $c_{\overleftrightarrow{ij}}$, 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 due to the round trip effect:

$$p_{ij}^{M} = \frac{1}{1+A_{ij}} \frac{\sigma}{\sigma-1} \left(w_j \tau_{ji} + w_i \tau_{ij} + c_{\overleftrightarrow{ij}} \right), \ A_{ij} = \frac{a_{ji}}{a_{ij}} \tag{A.9}$$

This price is higher than when transport firms are perfectly competitive, reflecting the higher equilibrium freight rates earlier.

The new equilibrium trade quantity and value on route ij are lower than the competitive equilibrium quantity and value:

$$\begin{aligned} q_{ij}^{M} &= \left[\left(\frac{\sigma}{\sigma-1} \right)^{2} \frac{1}{a_{ij}} \frac{1}{1+A_{ij}} \left(w_j \tau_{ji} + w_i \tau_{ij} + c_{\overleftrightarrow{ij}} \right) \right]^{-\sigma} \\ X_{ij}^{M} &= \left(\frac{\sigma}{\sigma-1} \right)^{2-\sigma} \frac{1}{a_{ij}}^{-\sigma} \left[\frac{1}{1+A_{ij}} \left(w_j \tau_{ji} + w_i \tau_{ij} + c_{\overleftrightarrow{ij}} \right) \right]^{1-\sigma}, \ A_{ij} = \frac{a_{ji}}{a_{ij}} \end{aligned} \tag{A.10}$$

When country j's import tariff on country i (τ_{ij}) increases, I showed earlier that there will be mitigating effects on j's import freight rates and spillover effects on j's export freight rates. Both of these result in an increase in the import and export prices as well as decreases in quantities and trade value. When the transport firm is a monopoly, both the mitigating and spillover effects are still present but the magnitudes are different: the mitigating effect is smaller while the spillover effect is bigger. Both of these result in bigger changes in prices, quantity, and value. The following lemma summarizes both the monopoly and comparative statics results from direct calculation:

Lemma 3. *When transport cost is endogenous, determined on a round trip basis by a monopolist transport firm, and under a demand function with pass-through greater than one, the equilibrium freight rates and prices are higher than when transport firms are competitive ($T_{ij}^{M} > T_{ij}^{R}$, $p_{ij}^{M} > p_{ij}^{R}$). The monopolist equilibrium trade quantities and value are lower than the competitive* *equilibria* ($q^M_{ij} < q^R_{ij}$, $X^M_{ij} < X^R_{ij}$).

An import tariff increase will affect both the origin country's imports and exports to its partner. The origin country's import freight rate is less responsive to tariffs than the competitive equilibrium—it falls by less. Import prices, quantity, and value are more responsive—prices increase by more while quantity and value falls by more:

$$\frac{\partial T^M_{ij}/\partial \tau_{ij}}{\partial T^R_{ij}/\partial \tau_{ij}} < 1\,,\ \frac{\partial p^M_{ij}/\partial \tau_{ij}}{\partial p^R_{ij}/\partial \tau_{ij}} > 1\,,\ \frac{\partial q^M_{ij}/\partial \tau_{ij}}{\partial q^R_{ij}/\partial \tau_{ij}} > 1 \ \textit{and}\ \frac{\partial X^M_{ij}/\partial \tau_{ij}}{\partial X^R_{ij}/\partial \tau_{ij}} > 1$$

On the export side, the origin country's export freight rate is more responsive to changes in tariffs—freight rates increases by more. Export prices, quantity, and value are also more responsive—prices increase by more while quantity and value falls by more:

$$\frac{\partial T^M_{ji}/\partial \tau_{ij}}{\partial T^R_{ji}/\partial \tau_{ij}} > 1\,,\ \frac{\partial p^M_{ji}/\partial \tau_{ij}}{\partial p^R_{ji}/\partial \tau_{ij}} > 1\,,\ \frac{\partial q^M_{ji}/\partial \tau_{ij}}{\partial q^R_{ji}/\partial \tau_{ij}} > 1 \ \textit{and}\ \frac{\partial X^M_{ji}/\partial \tau_{ij}}{\partial X^R_{ji}/\partial \tau_{ij}} > 1$$

A.4.3 Demand pass-through less than one

An example of a demand function with a pass-through that is less than one is the linear demand specification below. $\boldsymbol{a}_{ij}$ and $\boldsymbol{b}_{ij}$ are the demand intercept and slope respectively. I solve for the equilibrium under perfect competition first and then present the results under a monopoly transport firm.

$$p_{ij} = \boldsymbol{a}_{ij} - \boldsymbol{b}_{ij} q_{ij} \tag{A.11}$$

Under perfect competition and after substituting the profit-maximizing condition from the transport firm (equation (4)), the equilibrium freight rate for route ij under a linear demand function is as follows:

$$T^{R\prime}_{ij} = \frac{1}{1+B_{ij}}\left[B_{ij}(\boldsymbol{a}_{ij} - w_i\tau_{ij}) + c_{\overleftrightarrow{ij}} - \boldsymbol{a}_{ji} + w_j\tau_{ji}\right],\ B_{ij} = \frac{\boldsymbol{b}_{ji}}{\boldsymbol{b}_{ij}} \tag{A.12}$$

The equilibrium price of country i's good in j is increasing in the marginal cost of round trip transport $c_{\overleftrightarrow{ij}}$, 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, which is due to the round trip effect:

$$p^{R\prime}_{ij} = \frac{B_{ij}}{1+B_{ij}}\boldsymbol{a}_{ij} + \frac{1}{1+B_{ij}}\left(c_{\overleftrightarrow{ij}} - \boldsymbol{a}_{ji} + w_j\tau_{ji} + w_i\tau_{ij}\right),\ B_{ij} = \frac{\boldsymbol{b}_{ji}}{\boldsymbol{b}_{ij}} \tag{A.13}$$

The equilibrium trade quantity and value on route ij are as follows:

$$
\begin{aligned}
{q^{R\prime}}_{ij} &= \frac{1}{1+B_{ij}}\frac{1}{\boldsymbol{\beta}_{ij}}\left(\boldsymbol{\alpha}_{ij} - c_{\overleftrightarrow{ij}} + \boldsymbol{\alpha}_{ji} - w_j\tau_{ji} - w_i\tau_{ij}\right) \\
{X^{R\prime}}_{ij} &= {p^{R\prime}}_{ij}{q^{R\prime}}_{ij},\; B_{ij} = \frac{\boldsymbol{\beta}_{ji}}{\boldsymbol{\beta}_{ij}}
\end{aligned}
\tag{A.14}
$$

Under a monopoly transport firm and after substituting the equilibrium price from equation (2), we get the following:

$$
T_{ij} = \boldsymbol{\alpha}_{ij} - \boldsymbol{\beta}_{ij}q_{ij} - \tau_{ij}w_i \tag{A.15}
$$

Substituting the equation above into the optimal condition for a profit-maximizing transport monopolist (equation (A.7)), the equilibrium freight rate for route ij under a linear demand function is as follows and is higher than the perfect competition freight rate (equation (A.12)):

$$
{T^{M\prime}}_{ij} = \frac{1}{1+B_{ij}}\left[\left(B_{ij}+\frac{1}{2}\right)(\boldsymbol{\alpha}_{ij} - w_i\tau_{ij}) + \frac{1}{2}(c_{\overleftrightarrow{ij}} - \boldsymbol{\alpha}_{ji} + w_j\tau_{ji})\right],\; B_{ij} = \frac{\boldsymbol{\beta}_{ji}}{\boldsymbol{\beta}_{ij}} \tag{A.16}
$$

The new monopoly equilibrium price of country i's good in j is higher than under perfect competition (equation (A.13)) when $\boldsymbol{\alpha}_{ij} + \boldsymbol{\alpha}_{ji} \geq c_{\overleftrightarrow{ij}} + w_j\tau_{ji} + w_i\tau_{ij}$:

$$
{p^{M\prime}}_{ij} = \frac{B_{ij}}{1+B_{ij}}\boldsymbol{\alpha}_{ij} + \frac{1}{2(1+B_{ij})}\left(\boldsymbol{\alpha}_{ij} + c_{\overleftrightarrow{ij}} - \boldsymbol{\alpha}_{ji} + w_j\tau_{ji} + w_i\tau_{ij}\right),\quad B_{ij} = \frac{\boldsymbol{\beta}_{ji}}{\boldsymbol{\beta}_{ij}} \tag{A.17}
$$

The new equilibrium trade quantity and value on route ij are lower than the competitive equilibrium quantity and value (equation (A.14)):

$$
\begin{aligned}
{q^{M\prime}}_{ij} &= \frac{1}{1+B_{ij}}\frac{1}{2\boldsymbol{\beta}_{ij}}\left(\boldsymbol{\alpha}_{ij} - c_{\overleftrightarrow{ij}} + \boldsymbol{\alpha}_{ji} - w_j\tau_{ji} - w_i\tau_{ij}\right) \\
{X^{M\prime}}_{ij} &= {p^{M\prime}}_{ij}{q^{M\prime}}_{ij},\quad B_{ij} = \frac{\boldsymbol{\beta}_{ji}}{\boldsymbol{\beta}_{ij}}
\end{aligned}
\tag{A.18}
$$

From direct calculations, the following lemma summarizes both the monopoly and perfect competition results:

Lemma 4. *When transport cost is endogenous, determined on a round trip basis by a monopolist transport firm, and under a demand function with pass-through less than one, the equilibrium freight rates and prices are higher than when transport firms are competitive* (${T^{M\prime}}_{ij} > {T^{R\prime}}_{ij}$, ${p^{M\prime}}_{ij} > {p^{R\prime}}_{ij}$). *The monopolist equilibrium trade quantities and value are lower than the competi-*

tive equilibria ($q^{M\prime}_{ij} < q^{R\prime}_{ij}$, $X^{M\prime}_{ij} < X^{R\prime}_{ij}$).

An import tariff increase will affect both the origin country's imports and exports to its partner. The origin country's import freight rate is less responsive to tariffs than the competitive equilibrium—it falls by less. Import prices, quantity, and value are more responsive—prices increase by more while quantity and value falls by more:

$$\frac{\partial T^{M\prime}_{ij}/\partial\tau_{ij}}{\partial T^{R\prime}_{ij}/\partial\tau_{ij}} < 1\,,\ \frac{\partial p^{M'}_{ij}/\partial\tau_{ij}}{\partial p^{R\prime}_{ij}/\partial\tau_{ij}} > 1\,,\ \frac{\partial q^{M'}_{ij}/\partial\tau_{ij}}{\partial q^{R\prime}_{ij}/\partial\tau_{ij}} > 1 \text{ and } \frac{\partial X^{M'}_{ij}/\partial\tau_{ij}}{\partial X^{R\prime}_{ij}/\partial\tau_{ij}} > 1$$

On the export side, the origin country's export freight rate is more responsive to changes in tariffs—freight rates increases by more. Export prices, quantity, and value are also more responsive—prices increase by more while quantity and value falls by more:

$$\frac{\partial T^{M\prime}_{ji}/\partial\tau_{ij}}{\partial T^{R\prime}_{ji}/\partial\tau_{ij}} > 1\,,\ \frac{\partial p^{M'}_{ji}/\partial\tau_{ij}}{\partial p^{R\prime}_{ji}/\partial\tau_{ij}} > 1\,,\ \frac{\partial q^{M'}_{ji}/\partial\tau_{ij}}{\partial q^{R\prime}_{ji}/\partial\tau_{ij}} > 1 \text{ and } \frac{\partial X^{M'}_{ji}/\partial\tau_{ij}}{\partial X^{R\prime}_{ji}/\partial\tau_{ij}} > 1$$

Combining the results from both lemmas 3 and 4, the following proposition can be stated:

Proposition 2. *Under the assumption of imperfectly competitive transport firms, the mitigation and spillover impacts from the round trip effects could be larger or smaller relative to the perfect competition case, depending on whether the demand specification pass-through is greater or less than one:*

(i) When the demand specification has a pass-through of greater than one, the round trip effects from tariff changes are amplified: $\frac{\partial T^M_{ij}/\partial\tau_{ij}}{\partial T_{ij}/\partial\tau_{ij}} < 1$, $\frac{\partial p^M_{ij}/\partial\tau_{ij}}{\partial p_{ij}/\partial\tau_{ij}} > 1$, $\frac{\partial q^M_{ij}/\partial\tau_{ij}}{\partial q_{ij}/\partial\tau_{ij}} > 1$, $\frac{\partial X^M_{ij}/\partial\tau_{ij}}{\partial X_{ij}/\partial\tau_{ij}} > 1$, $\frac{\partial T^M_{ji}/\partial\tau_{ij}}{\partial T_{ji}/\partial\tau_{ij}} > 1$, $\frac{\partial p^M_{ji}/\partial\tau_{ij}}{\partial p_{ji}/\partial\tau_{ij}} > 1$, $\frac{\partial q^M_{ji}/\partial\tau_{ij}}{\partial q_{ji}/\partial\tau_{ij}} > 1$ *and* $\frac{\partial X^M_{ji}/\partial\tau_{ij}}{\partial X_{ji}/\partial\tau_{ij}} > 1$

(ii) When the demand specification has a pass-through of less than one, the opposite is true.

A.5 Discussion on the bias between OLS and IV

In this section, I introduce a simple model that illustrates the two sources of bias in this paper, simultaneous equation bias and bias induced by the round trip effect, and show that they contribute to a larger difference between the OLS and IV estimates as predicted by my results. Next, I provide an analytical solution to the supply elasticity using this model. I then solve for the implied supply elasticity using my IV and OLS estimates and show that it is in the ballpark of available supply elasticities in the literature.

There are two sources of bias here as discussed in the paper: (1) simultaneous equation bias since the supply and demand for transport services on a particular route ij is simultaneously determined, and (2) bias induced by the round trip effect where transport supply for routes ij and ji are jointly determined, leading to a negative relationship between the transport prices on route ij and ji.

To incorporate the simultaneous equation bias, I introduce the variables Q_{ij} and T_{ij} (quantity and price) in the route ij market for transport services which are jointly determined by the demand equation:

$$\ln Q_{ij} = -\beta_1 \ln T_{ij} + e_1 \tag{A.19}$$

and the supply equation, which includes the round trip effect where transport supply for routes ij and ji are jointly determined (as predicted in the theory section):

$$\ln Q_{ij} = \beta_2 \ln\left(T_{ij} + T_{ji}\right) + e_2 \tag{A.20}$$

Assume $e = (e_1, e_2)$ satisfies $\mathbb{E}[e] = 0$ and $\mathbb{E}[ee'] = \begin{bmatrix} \mathbb{V}[e_1] & 0 \\ 0 & \mathbb{V}[e_2] \end{bmatrix}$ where $\mathbb{V}[\cdot] \geq 1$ is the variance of the errors in each regression.

The round trip effect results in a negative relationship between the transport prices on route ij and ji which introduces the second bias (as predicted from the profit maximization condition in the theory section equation (4)):

$$T_{ji} = -\beta_3 T_{ij} + c_{\overleftrightarrow{ij}} \tag{A.21}$$

where $c_{\overleftrightarrow{ij}}$ is the marginal cost servicing the round trip between i and j.

Substituting equation (A.21) into equation (A.20), we can rewrite the supply equation as a function of prices on route ij (T_{ij}):

$$\ln Q_{ij} = \beta_2 \ln\left(T_{ij} - \beta_3 T_{ij} + c_{\overleftrightarrow{ij}}\right) + e_2$$

Taking the first order Taylor series approximation for function $f(x) \equiv x - \beta_3 x + c_{\overleftrightarrow{ij}}$ where $x = \ln T_{ij}$ evaluated at point $\ln T_0$ and utilizing the chain rule, we have the following:

$$\ln\left(T_{ij} - \beta_3 T_{ij} + c_{\overleftrightarrow{ij}}\right) \approx \underbrace{\frac{(1-\beta_3)\, T_0}{(1-\beta_3)\, T_0 + c_{\overleftrightarrow{ij}}}}_{\equiv A<1} \ln T_{ij} + \mathbb{C}$$

where $\mathbb{C}$ is a constant.[6] The term A is less than 1 since from Figure 2 in Section 4 we know that $|\beta_3| < 1$, in levels as well as logs. This allows us to rewrite the supply equation (A.20) as

$$\ln Q_{ij} = A\beta_2 \ln\left(T_{ij}\right) + e_2$$

where A is the bias introduced by the round trip effect. We can then solve for Q_{ij} and T_{ij} in terms of the errors. In matrix notation,

$$\begin{aligned}
\begin{bmatrix} 1 & \beta_1 \\ 1 & -A\beta_2 \end{bmatrix} \begin{bmatrix} \ln Q_{ij} \\ \ln T_{ij} \end{bmatrix} &= \begin{bmatrix} e_1 \\ e_2 \end{bmatrix} \\
\begin{bmatrix} \ln Q_{ij} \\ \ln T_{ij} \end{bmatrix} &= \begin{bmatrix} 1 & \beta_1 \\ 1 & -A\beta_2 \end{bmatrix}^{-1} \begin{bmatrix} e_1 \\ e_2 \end{bmatrix} \\
&= \begin{bmatrix} \frac{1}{\beta_1 + A\beta_2}\left(A\beta_2 e_1 + \beta_1 e_2\right) \\ \frac{1}{\beta_1 + A\beta_2}\left(e_1 - e_2\right) \end{bmatrix}
\end{aligned}$$

Regressing $\ln Q_{ij}$ on $\ln T_{ij}$ (projection of $\ln Q_{ij}$ on $\ln T_{ij}$) yields $\ln Q_{ij} = \beta^* \ln T_{ij} + e^*$ with $\mathbb{E}[\ln T_{ij} e^*] = 0$ and the coefficient defined by projection as

$$\beta^* = \frac{\mathbb{E}[\ln T_{ij} \ln Q_{ij}]}{\ln T_{ij}^2} = \frac{A\beta_2 \mathbb{V}[e_1] - \beta_1 \mathbb{V}[e_2]}{\mathbb{V}[e_1] + \mathbb{V}[e_2]} \tag{A.22}$$

where β^* is the OLS coefficient from Table 4 which is neither the demand (β_1) nor supply (β_2) slope—the result of simultaneous equation bias. β^* approximates the average of β_1 and β_2 and as a result attenuates to zero. Holding constant the supply elasticity β_2, just the

[6] Constant $\mathbb{C} = f(\ln T_0) - \frac{(1-\beta_3)T_0}{(1-\beta_3)T_0 + c_{\overleftrightarrow{ij}}} \ln T_0$.

simultaneous equation bias would result in a larger difference between the IV and OLS estimates. Similarly, the round trip effect bias introduced by A decreases β_2 which would also result in a relatively larger difference between the IV and OLS estimates. Combined, both these sources of bias contribute to larger magnitude differences between the OLS and IV estimates, as predicted in my results ($|\beta_1| > |\beta^*|$).

Second, I provide an analytical solution to the supply elasticity (β_2) using this model. I then calibrate and solve for a comparable supply elasticity and show that it is in the ballpark of available supply elasticities in the literature. The analytical solution for the supply elasticity is below (equation (A.22)):

$$\beta_2 = \frac{1}{A\mathbb{V}[e_1]}\Big[\big(\mathbb{V}[e_1] + \mathbb{V}[e_2]\big)\,\beta^* + \beta_1\mathbb{V}[e_2]\Big] \tag{A.23}$$

Next, I calibrate the equation above. The demand elasticity β_2 and OLS estimates β^* are taken directly from Table 4. In order to compare this elasticity to supply elasticities estimated in the literature, I convert β_2 to the appropriate units. I do this in two ways. First, supply elasticities in the literature is estimated as the elasticity of trade on route ij with respect to price on the same route. Here, β_2 is the elasticity of trade on route ij with respect to price on route ij as well as the inverse route ji (equation (A.20)). β_2 will therefore be larger than typical supply elasticities since prices are negatively correlated here due to the round trip effect. As such, I normalize A to one. Second, demand elasticity β_1 is estimated at the monthly level here while typical elasticities are estimated at the annual level. So I scale β_2 using the annual demand elasticity estimated in the paper (Table 6). Figure 1 plots the elasticity estimates allowing for the error variance to range from 1 to 2 for both the demand and supply equations. Assuming the variance of the errors in the demand regression (Table 4) is approximately the same as the errors in the supply regression, the implied supply elasticity in this model is about 0.78. This is in the ballpark of Broda, Limao and Weinstein (2008) who estimates a median elasticity of supply of 0.6 across 15 importers annually over the period 1994-2003.

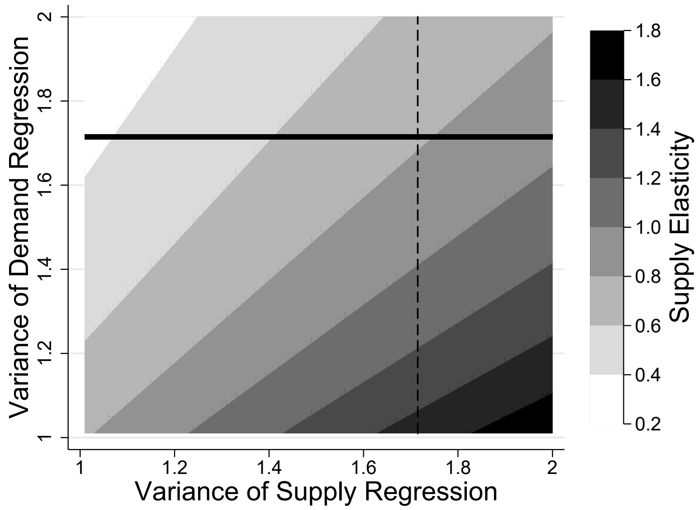


Figure A.8: Supply elasticity estimate

Notes: Horizontal line indicates the variance of the errors in the demand regression from Table 4 (1.17). Vertical dashed line indicates the same variance for comparison. Supply elasticity has been annualized. Source: Authors' calculations. ■

A.6 Counterfactual Appendix: Discussion on mitigation effects

The over-prediction of the fall in imports between the counterfactual results in the exogenous and round trip model, known as the mitigation effects, are large and robust to using a different trade elasticity estimates. This is generally due to both trade elastiticies increasing the response to tariffs with and without the round trip endogenous adjustment proportionally. This section discusses the model and data features that drive this result. I confirm this result directly by first showing a high correlation of 0.9 of between the route-level mitigation effects using both elasticities (Figure A.9).

Analytically, we can also show that the counterfactual trade flow differences under the round trip model and exogenous model are similar under both elasticities. The route ij equilibrium trade value for the exogenous model (X_{ij}^{Exo}) and the round trip model (X_{ij}^{*}) are as follows:

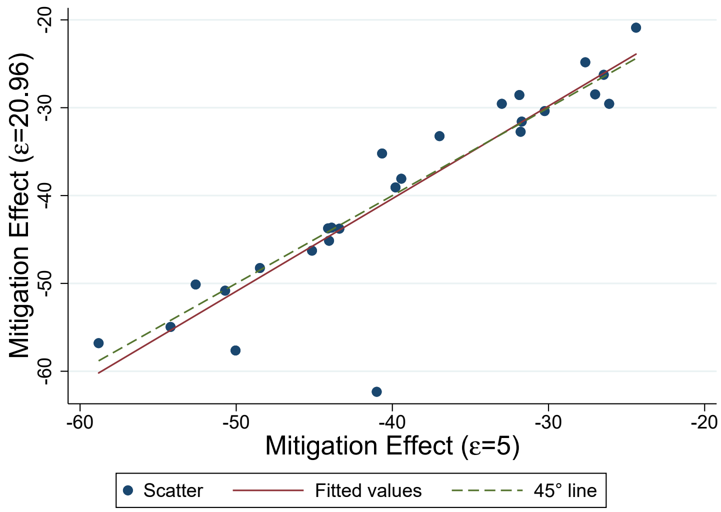


Figure A.9: Robustness Check of Mitigation Effects

Notes: Correlation of 0.9 for 26 routes. Mitigation effect on y-axis is calculated using a trade elasticity of 20.1 while the x-axis is calculated using a trade elasticity of 5.
Source: Authors' calculations using Census Bureau, Drewry, International Labor Organization (ILO), OECD, and WITS. ■

$$
\begin{aligned}
X_{ij}^{Exo} &= \left[\frac{\epsilon}{\epsilon-1}\frac{1}{a_{ij}}\right]^{-\epsilon}\left[w_i\tau_{ij}+\frac{c_{ij}}{l_{ij}}\right]^{1-\epsilon} \\
X_{ij}^{*} &= \left[\frac{\epsilon}{\epsilon-1}\frac{1}{a_{ij}}\right]^{-\epsilon}\left[\frac{1}{1+Y_{ij}}\left(w_i\tau_{ij}+\frac{1}{l_{ij}}\left(c_{\overleftrightarrow{ij}}+l_{ji}w_j\tau_{ji}\right)\right)\right]^{1-\epsilon}, \qquad \text{(A.24)} \\
\text{where } Y_{ij} &= \frac{a_{ji}}{a_{ij}}\left(\frac{l_{ji}}{l_{ij}}\right)^{1+1/\epsilon}
\end{aligned}
$$

The two main parameters of interest are the preference parameters (a_{ji} and a_{ij}) and loading factors (l_{ij} and l_{ji}) for both routes. The preference parameters govern the utility preferences for goods on these routes while the loading factor converts the quantity of goods on these routes into a common unit (for example, a containership or a container).

The counterfactual changes only affects import tariffs (wlog say this is country j's perspective: a change in τ_{ij} to τ_{ij}'). The mitigation effect for each route is the difference between the counterfactual trade value changes for both scenarios, the exogenous and the round trip model:

$$\begin{aligned}
\frac{\triangle X_{ij}^{Exo} - \triangle X_{ij}^{*}}{\triangle X_{ij}^{Exo}} &\equiv \frac{X_{ij}^{Exo}(\tau_{ij}') - X_{ij}^{Exo}(\tau_{ij}) - \left(X_{ij}^{*}(\tau_{ij}') - X_{ij}^{*}(\tau_{ij})\right)}{X_{ij}^{Exo}(\tau_{ij}') - X_{ij}^{Exo}(\tau_{ij})} \\
&= 1 - \left(\frac{1}{1+Y_{ij}}\right)^{1-\epsilon} \frac{\left(w_i\tau_{ij}' + \Gamma_{ij}\right)^{1-\epsilon} - \left(w_i\tau_{ij} + \Gamma_{ij}\right)^{1-\epsilon}}{\left(w_i\tau_{ij}' + \Gamma_{ij}^{Exo}\right)^{1-\epsilon} - \left(w_i\tau_{ij} + \Gamma_{ij}^{Exo}\right)^{1-\epsilon}} \qquad \text{(A.25)} \\
&\text{where } Y_{ij} = \frac{a_{ji}}{a_{ij}}\left(\frac{l_{ji}}{l_{ij}}\right)^{1+1/\epsilon}, \Gamma_{ij} = \frac{1}{l_{ij}}\left(c_{\overleftrightarrow{ij}} + l_{ji}w_j\tau_{ji}\right), \\
&\text{and } \Gamma_{ij}^{Exo} = \frac{c_{ij}}{l_{ij}}
\end{aligned}$$

Here we can see that for relatively close values of trade elasticity ϵ, the mitigation effect changes will be roughly similar. This is particularly true because the first counterfactual changes in tariffs is small: a doubling in US import tariffs from a relatively low average of 1.33 percent. As a result of the small tariff changes, the third term in equation (A.25) below approximates one. The tariff changes in the second counterfactual are relatively larger which results in slightly bigger differences in the mitigation effects.

Lastly, I show that the unit-adjusted relative preferences for routes are driving the mitigation effects. A higher unit-adjusted relative preference for route ij means that consumers have a higher preference for ij goods compared to ji goods. This means that an increase in ij import tariffs (j's import tariffs on i) will have less of an impact on decreasing import flows due to this high relative preference. As a result, the mitigation impact from the round trip effect for route ij will be smaller. I confirm that this is the case by showing a highly positive correlation of 0.96 between the route-level unit-adjusted relative preferences against its mitigation effects.

Since the third term in equation (A.25) above approximates the difference in tariff levels, we can see that what will be driving the overall mitigation effect is the second term in the equation—$\left(\frac{1}{1+Y_{ij}}\right)^{1-\epsilon}$. We can interpret $\left[\frac{a_{ij}}{a_{ji}}\left(\frac{l_{ij}}{l_{ji}}\right)^{1+1/\epsilon}\right]$ as the unit-adjusted relative preference for a route by rewriting it as follows:

$$\left(\frac{1}{1+Y_{ij}}\right)^{1-\epsilon} = \left(\frac{1}{1+\frac{a_{ji}}{a_{ij}}\left(\frac{l_{ji}}{l_{ij}}\right)^{1+1/\epsilon}}\right)^{1-\epsilon} = \left[1+\left(\frac{a_{ij}}{a_{ji}}\left(\frac{l_{ij}}{l_{ji}}\right)^{1+1/\epsilon}\right)^{-1}\right]^{\epsilon-1}$$

All else equal, a higher unit-adjusted preference for route ij's goods relative to opposite direction route ji will decrease this second term:

$$\frac{\partial\left(\frac{1}{1+Y_{ij}}\right)^{1-\epsilon}}{\partial\left[\frac{a_{ij}}{a_{ji}}\left(\frac{l_{ij}}{l_{ji}}\right)^{1+1/\epsilon}\right]} = (\epsilon-1)\left[1+\left(\frac{a_{ij}}{a_{ji}}\left(\frac{l_{ij}}{l_{ji}}\right)^{1+1/\epsilon}\right)^{-1}\right]^{\epsilon}\left[-\left(\frac{a_{ij}}{a_{ji}}\left(\frac{l_{ij}}{l_{ji}}\right)^{1+1/\epsilon}\right)^{-2}\right] < 0$$

Using the chain rule, the mitigation effect is decreasing in the unit-adjusted relative preference for a route:

$$\frac{\partial\frac{\triangle X_{ij}^{Exo}-\triangle X_{ij}^{*}}{\triangle X_{ij}^{Exo}}}{\partial\left[\frac{a_{ij}}{a_{ji}}\left(\frac{l_{ij}}{l_{ji}}\right)^{1+1/\epsilon}\right]} = \underbrace{\frac{\partial\frac{\triangle X_{ij}^{Exo}-\triangle X_{ij}^{*}}{\triangle X_{ij}^{Exo}}}{\partial\left(\frac{1}{1+Y_{ij}}\right)^{1-\epsilon}}}_{>0}\underbrace{\frac{\partial\left(\frac{1}{1+Y_{ij}}\right)^{1-\epsilon}}{\partial\left[\frac{a_{ij}}{a_{ji}}\left(\frac{l_{ij}}{l_{ji}}\right)^{1+1/\epsilon}\right]}}_{<0} < 0$$

All else equal, a higher unit-adjusted relative preference for route ij means that consumers have a higher preference for ij goods compared to ji goods. An increase in ij's import tariffs will then have less of an impact on decreasing import flows due to this high relative preference. As a result, the mitigation impact from the round trip effect will be smaller.

I show that this is indeed the case by plotting the route-level unit-adjusted relative preferences against its mitigation effects below (figure A.10). This relationship is positive and highly correlated with a coefficient of 0.96. Routes with high unit-adjusted relative preferences like Busan-NY, Shanghai-LA or Shanghai-Houston have lower mitigation effects relative to routes like Felixstowe-LA or Genoa-Houston.

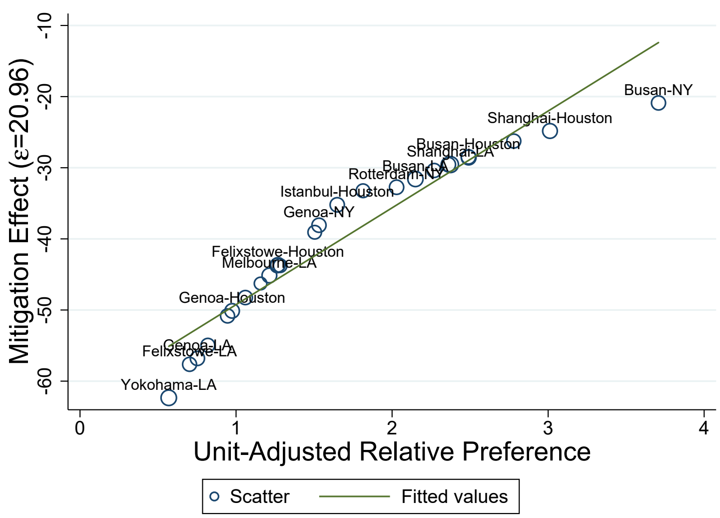


Figure A.10: Positive Relationship between Mitigation Effects and Relative Preference

Notes: Correlation of 0.96 for 26 routes. Weighted by total trade value by route.
Source: Authors' calculations using Census Bureau, Drewry, International Labor Organization (ILO), OECD, and WITS.

■

B Online Appendix

B.1 Additional Tables and Figures

Table A.5: Containerized Trade Demand Estimates for All Countries

	(1) OLS	(2) OLS	(3) IV	(4) IV
Panel A: ln Trade Value				
ln Freight Rate	-0.532	-0.460	-3.873	-2.884
	(0.0969)	(0.110)	(1.232)	(0.956)
Panel B: ln Trade Weight				
ln Freight Rate	-0.716	-0.633	-5.222	-4.072
	(0.118)	(0.133)	(1.613)	(1.256)
Panel C: ln Trade Value per Weight				
ln Freight Rate	0.184	0.173	1.349	1.188
	(0.0365)	(0.0377)	(0.427)	(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
KP F-Stat			8.433	7.750

Notes: Robust standard errors in parentheses are clustered by route. 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. 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. Table A.6 presents the first stage regressions.
Sources: Drewry, Census Bureau, and author's calculations. ■

Table A.6: First-Stage Regressions of Containerized Trade Demand Estimates for All Countries (table A.5)

	(1) ln Freight Rate	(2) ln Freight Rate
ln Opp Dir Predicted Trade Value	0.0227	0.0227
	(0.00781)	(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

Notes: Robust standard errors in parentheses are clustered by route. 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, Census Bureau, and author's calculations. ■

Table A.7: Containerized Trade Value Demand Estimates using Aggregate Data for OECD Countries

	(1) OLS	(2) IV	(3) First-Stage
Panel A: ln Trade Value			
ln Freight Rate	-0.132	-4.137	
	(0.307)	(1.506)	
ln Opp Dir Predicted Trade Value			0.0391
			(0.0138)
Panel B: ln Trade Weight			
ln Freight Rate	-0.415	-6.319	
	(0.464)	(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

Notes: Robust standard errors in parentheses are clustered by route. Results are robust to clustering at the dyad level. 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, Census Bureau, and author's calculations. ■

Table A.8: Containerized Trade Demand Estimates for OECD Countries with 2009 instrument

	(1) OLS	(2) OLS	(3) IV	(4) IV
Panel A: ln Trade Value				
ln Freight Rate	-0.640	-0.503	-1.919	-1.044
	(0.147)	(0.131)	(0.715)	(0.670)
Panel B: ln Trade Weight				
ln Freight Rate	-1.014	-0.808	-2.436	-1.302
	(0.195)	(0.175)	(0.878)	(0.778)
Panel C: ln Trade Value per Weight				
ln Freight Rate	0.374	0.305	0.518	0.258
	(0.0688)	(0.0675)	(0.200)	(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
KP F-Stat			27.12	26.43

Notes: Robust standard errors in parentheses are clustered by route. 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.9 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, Census Bureau, and author's calculations. ∎

Table A.9: First-Stage Regressions of Containerized Trade Demand Estimates for OECD Countries with 2009 instrument (table A.8)

	(1) ln Freight Rate	(2) ln Freight Rate
ln Opp Dir Predicted Trade Value	0.0511	0.0485
	(0.00981)	(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

Notes: Robust standard errors in parentheses are clustered by route. 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, Census Bureau, and author's calculations. ■

B.2 Simple Model to Illustrate 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:

$$Q_{ji}^{D} = D^{i} - d^{i} T_{ji} \text{ and } Q_{ij}^{D} = D^{j} - d^{j} T_{ij} \tag{A.26}$$

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.

B.2.1 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:

$$\bar{Q}_{ji}^{S} = C_{ji} + c_{ji} T_{ji} \text{ and } \bar{Q}_{ij}^{S} = C_{ij} + c_{ij} T_{ij} \tag{A.27}$$

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.[1]

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

$$\begin{aligned} \bar{T}_{ji}^{*} &= \frac{1}{d^{i} + c_{ji}} \left(D^{i} - C_{ji} \right) \text{ and } \bar{Q}_{ji}^{*} = \frac{1}{d^{i} + c_{ji}} \left(c_{ji} D^{i} + d^{i} C_{ji} \right) \\ \bar{T}_{ij}^{*} &= \frac{1}{d^{j} + c_{ij}} \left(D^{j} - C_{ij} \right) \text{ and } \bar{Q}_{ij}^{*} = \frac{1}{d^{j} + c_{ij}} \left(c_{ij} D^{j} + d^{j} C_{ij} \right) \end{aligned} \tag{A.28}$$

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

[1] One interpretation is that there are a continuum of small transport firms providing transport between the two countries who face heterogenous marginal costs.

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.

B.2.2 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.[2] 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 ($c_{\overleftrightarrow{ij}}$):[3]

$$Q^S_{ij} = Q^S_{ji} \equiv Q^S_{\overleftrightarrow{ij}} = C_{\overleftrightarrow{ij}} + c_{\overleftrightarrow{ij}} \left(T_{ji} + T_{ij} \right) \tag{A.29}$$

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

$$\begin{aligned}
T^*_{ji} &= \frac{1}{c_{\overleftrightarrow{ij}} d^i + c_{\overleftrightarrow{ij}} d^j + d^i d^j} \left[\left(d^j + c_{\overleftrightarrow{ij}} \right) D^i - c_{\overleftrightarrow{ij}} D^j - d^j C_{\overleftrightarrow{ij}} \right] \\
T^*_{ij} &= \frac{1}{c_{\overleftrightarrow{ij}} d^i + c_{\overleftrightarrow{ij}} d^j + d^i d^j} \left[\left(d^i + c_{\overleftrightarrow{ij}} \right) D^j - c_{\overleftrightarrow{ij}} D^i - d^i C_{\overleftrightarrow{ij}} \right] \\
Q^*_{ji} = Q^*_{ij} \equiv Q^* &= \frac{C_{\overleftrightarrow{ij}}}{c_{\overleftrightarrow{ij}} d^i + c_{\overleftrightarrow{ij}} d^j + d^i d^j} + \frac{D^i}{\left(d^j + c_{\overleftrightarrow{ij}} \right) d^i} + \frac{D^j}{\left(d^i + c_{\overleftrightarrow{ij}} \right) d^j}
\end{aligned} \tag{A.30}$$

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^*_{ji}). The equilibrium quantity of transport services for both routes is increasing in the

[2]If demand between these markets are asymmetric enough, there may be some transport firms going empty one way ((Ishikawa and Tarui, 2018)). 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.5 elaborates.

[3]These costs are assumed to be the same here. It is possible to relax this assumption without changing the main results.

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 good(D^i) increases while holding the other parameters constant. This raises the equilibrium transport price on route ji (equation (A.30)) 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 (A.30)). 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'^D_{ji} is the new demand curve after the shock on i's demand intercept for j ($\hat{D}^i > D^i$). Q'^S_{ij} is the new transport supply on opposite route ij which results in a lower equilibrium transport price T'^*_{ij}.[4]

B.3 Data Appendix

B.3.1 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

[4]The new lower opposite route transport price T'^*_{ij} will also shift the route ji supply (Q'^S_{ji}, equation (A.29)).

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.10 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.10). With the number of containers, I can calculate the average value and weight per container. The 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.

Table A.10: Summary Statistics of aggregate data set matched with container volumes per year

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

Notes: 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, MARAD, and author's calculations ■

In the last row of table A.10, 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%.[5] 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.

B.4 Theory Proofs

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 (A.1)): $\frac{\partial p_{ij}^{Exo}}{\partial \tau_{ij}} = w_i > 0$. From equation (A.2), the derivative of j's import quantity from i with respect to its import tariff on i is negative: $\frac{\partial q_{ij}^{Exo}}{\partial \tau_{ij}} = -\epsilon w_i \left(w_i \tau_{ij} + c_{ij}\right)^{-\epsilon-1} \left[\frac{\epsilon}{\epsilon-1}\frac{1}{a_{ij}}\right]^{-\epsilon} < 0$. From equation (A.2), the derivative of j's import quantity from i with respect to its import tariff on i is also negative: $\frac{\partial X_{ij}^{Exo}}{\partial \tau_{ij}} = -\left(\epsilon-1\right) w_i \left(w_i \tau_{ij} + c_{ij}\right)^{-\epsilon} \left[\frac{\epsilon}{\epsilon-1}\frac{1}{a_{ij}}\right]^{-\epsilon} < 0$.

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 (7)): $\frac{\partial T_{ij}^{R}}{\partial \tau_{ij}} = -\frac{1}{1+A_{ij}} w_i < 0$.

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 (8)) 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 (9), the deriva-

[5] This average measure is in the ballpark with the 6.7% container freight per value average in Rodrigue, Comtois and Slack (2013).

tive of the trade quantity from i to j with respect to j's import tariff on i is negative:

$$\frac{\partial q_{ij}^{R}}{\partial \tau_{ij}} = -\epsilon w_i \left(\frac{\epsilon}{\epsilon - 1} \frac{1}{a_{ij}} (\frac{1}{1 + A_{ij}} \right)^{-\epsilon} \left(w_j \tau_{ji} + w_i \tau_{ij} + c_{\overleftrightarrow{ij}} \right)^{-\epsilon-1} < 0$$

From equation (9), the derivative of the trade value from i to j with respect to j's import tariff on i is negative: $\frac{\partial X_{ij}^{R}}{\partial \tau_{ij}} = -\left(\epsilon - 1\right) w_i \left(\frac{1}{1+A_{ij}} \right)^{1-\epsilon} \left[\frac{\epsilon}{\epsilon-1} \frac{1}{a_{ij}} \left(w_j \tau_{ji} + w_i \tau_{ij} + c_{\overleftrightarrow{ij}} \right) \right]^{-\epsilon} < 0.$

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:

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

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

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

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 (A.3)): $\frac{\partial T_{ji}^{R}}{\partial \tau_{ij}} = \frac{1}{1+A_{ij}^{-1}} w_i > 0$. 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 (A.4)): $\frac{\partial p_{ji}^{R}}{\partial \tau_{ij}} = \frac{1}{1+A_{ij}^{-1}} w_i > 0$. 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 (A.4)): $\frac{\partial q_{ji}^{R}}{\partial \tau_{ij}} = -\epsilon w_i \left(\frac{\epsilon}{\epsilon-1} \frac{1}{a_{ji}} (\frac{1}{1+A_{ij}^{-1}} \right)^{-\epsilon} \left(w_j \tau_{ji} + w_i \tau_{ij} + c_{\overleftrightarrow{ij}} \right)^{-\epsilon-1} < 0$. The derivative of j's export value to i with respect to j's preference for i's good is negative (equation (A.4)): $\frac{\partial X^R_{ji}}{\partial \tau_{ij}} = -(\epsilon - 1)\, w_i \left(\frac{1}{1+A^{-1}_{ij}}\right)^{1-\epsilon} \left[\frac{\epsilon}{\epsilon-1}\frac{1}{a_{ji}}\left(w_j\tau_{ji} + w_i\tau_{ij} + c_{\overleftrightarrow{ij}}\right)\right]^{-\epsilon} < 0$.

Proof of Lemma 2 This lemma can be proven via direct calculation following lemma 1's proof.

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 (A.2)): $\frac{\partial q^{Exo}_{ij}}{\partial a_{ij}} = \epsilon a^{\epsilon-1}_{ij}\left[\frac{\epsilon}{\epsilon-1}\left(w_i\tau_{ij} + c_{ij}\right)\right]^{-\epsilon} > 0$. The derivative of j's import value from i with respect to j's preference for i's good is also positive (equation (A.2)): $\frac{\partial X^{Exo}_{ij}}{\partial a_{ij}} = \epsilon a^{\epsilon-1}_{ij}\left(\frac{\epsilon}{\epsilon-1}\right)^{-\epsilon}\left(w_i\tau_{ij} + c_{ij}\right)^{1-\epsilon} > 0$. Country j's import price from i does not change with its preference for i's good (equation (A.1)): $\frac{\partial p^{Exo}_{ij}}{\partial a_{ij}} = 0$.

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, $\frac{\partial A_{ji}}{\partial a_{ij}} = \frac{1}{a_{ij}}A^{-1}_{ij} > 0$.

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 (7)): $\frac{\partial T^R_{ij}}{\partial a_{ij}} = \frac{1}{a_{ij}}\frac{1}{1+A_{ij}}\frac{1}{1+A^{-1}_{ij}}\left[w_i\tau_{ij} + w_j\tau_{ji} + c_{\overleftrightarrow{ij}}\right] > 0$.

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 (8)) 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: $\frac{\partial p^R_{ij}}{\partial a_{ij}} = \frac{1}{a_{ij}}\frac{1}{1+A_{ij}}\frac{1}{1+A^{-1}_{ij}}\left[w_i\tau_{ij} + w_j\tau_{ji} + c_{\overleftrightarrow{ij}}\right] > 0$.

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 (9), the derivative of the trade quantity from i to j with respect to j's preference for i's good is positive: $\frac{\partial q^R_{ij}}{\partial a_{ij}} = \epsilon\left(\frac{1}{a_{ij}}\right)^{1-\epsilon}\left(\frac{1}{1+A_{ij}}\right)^{1-\epsilon}\left[\frac{\epsilon}{\epsilon-1}\left(w_j\tau_{ji} + w_i\tau_{ij} + c_{\overleftrightarrow{ij}}\right)\right]^{-\epsilon} > 0$. From equation (9), the derivative of the trade value from i to j with respect to j's preference for i's good is positive: $\frac{\partial X^R_{ij}}{\partial a_{ij}} = \left(\epsilon + A_{ij}\right)\left(\frac{1}{a_{ij}}\right)^{1-\epsilon}\left(\frac{1}{1+A_{ij}}\right)^{2-\epsilon}\left[\frac{\epsilon}{\epsilon-1}\right]^{-\epsilon}\left(w_j\tau_{ji} + w_i\tau_{ij} + c_{\overleftrightarrow{ij}}\right)^{1-\epsilon} > 0$.

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:

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

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

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

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 (A.3)): $\frac{\partial T_{ji}^R}{\partial a_{ij}} = -\frac{1}{a_{ij}}\frac{1}{1+A_{ij}}\frac{1}{1+A_{ij}^{-1}}\left[w_i\tau_{ij}+w_j\tau_{ji}+c_{\overleftrightarrow{ij}}\right] < 0$. 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 (A.4)): $\frac{\partial p_{ji}^R}{\partial a_{ij}} = -\frac{1}{a_{ij}}\frac{1}{1+A_{ij}}\frac{1}{1+A_{ij}^{-1}}\left[w_i\tau_{ij}+w_j\tau_{ji}+c_{\overleftrightarrow{ij}}\right] < 0$. 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 (A.4)): $\frac{\partial q_{ji}^R}{\partial a_{ij}} = \epsilon\frac{1}{a_{ij}}\frac{1}{1+A_{ij}}\left(\frac{1}{1+A_{ij}^{-1}}\right)^{-\epsilon}\left[\frac{\epsilon}{\epsilon-1}\frac{1}{a_{ji}}\left(w_j\tau_{ji}+w_i\tau_{ij}+c_{\overleftrightarrow{ij}}\right)\right]^{-\epsilon} > 0$. The derivative of j's export value to i with respect to j's preference for i's good is positive (equation (A.4)): $\frac{\partial X_{ji}^R}{\partial a_{ij}} = (\epsilon-1)\frac{1}{a_{ij}}\frac{1}{1+A_{ij}}\left(\frac{1}{1+A_{ij}^{-1}}\right)^{1-\epsilon}\left[\frac{\epsilon}{\epsilon-1}\frac{1}{a_{ji}}\right]^{-\epsilon}\left(w_j\tau_{ji}+w_i\tau_{ij}+c_{\overleftrightarrow{ij}}\right)^{1-\epsilon} > 0$.

B.5 The Round Trip Effect and Search Model

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 relies on the assumption the quantity of goods transported between these countries are the same.[6] 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.[7]

This section investigates the robustness of result by relaxing this main assumption. I start with the same Armington trade model in the main theory model with a transportation industry constrained to service a round trip. The difference in this model 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 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 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

[6] This assumption is ultimately relaxed in the counterfactual section 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.

[7] 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 freight rates are nonzero, the balanced quantity equilibrium is chosen to be the focus.

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 B.5.2 to B.5.6 highlight each stage respectively. Section B.5.7 characterizes the equilibrium and section B.5.8 presents the main predictions of the model

B.5.1 Model Setup

The trade model is the same augmented partial equilibrium Armington model with multiple countries as the baseline model from Hummels, Lugovskyy and Skiba (2009) with three types of agents: consumers, manufacturing firms, and transport firms. 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 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, Lugovskyy 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.5.2 Consumer demand

I assume that the world consists of M potentially heterogeneous countries where each country produces a different variety (ω) of a tradeable good.[8] 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

$$U_j = q_{j0} + \int^{M} a_{ij} q_{ij}(\omega)^{(\sigma-1)/\sigma} d\omega, \;\; \sigma > 1 \tag{A.31}$$

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,[9] q_{ij} the quantity of variety consumed on route ij, while σ is the price elasticity of demand.[10] The numeraire good, interpreted as services here, is costlessly traded and its price is normalized to one.

B.5.3 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 the baseline model—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

[8] There is one exporter per country and so the good variety ω translates into the productivity draw of the exporter firm φ.

[9] Preference parameter a_{ij} can also be interpreted as the attractiveness of country i's product to country j (Head and Mayer, 2014).

[10] Similar to Hummels, Lugovskyy and Skiba (2009), σ is the price elasticity of demand: $\frac{\partial q_{ij}}{\partial p_{ij}} \frac{q_{ij}}{p_{ij}} = -\sigma$ (equation (A.31)).

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 variety.[11] Carrier are homogeneous and incur cost ψ_{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 ρ. 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 φ 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}), $\left[\left(p_{ij}(\varphi) - t_{ij}(\varphi)\right) q_{ij}(\varphi))\right]$.[12] If not, the goods expire and are not sold.[13] 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 $\left(t_{ij}(\varphi)q_{ij}(\varphi) - \psi_{ij}\right)$. 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 a exporter meets a carrier, they negotiate a transport price where one of the

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

[12]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 τ_{ij}, the producer surplus is $\left(p_{ij}(\varphi) - t_{ij}(\varphi) - \tau_{ij}\right) q_{ij}(\varphi))$.

[13]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. This version is chosen for simplicity.

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 φ and $V_{C,ij}$ be the expected payoff of a carrier. The bargaining problem between exporter and carrier is as follows:

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

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, ψ_{ij} is the cost to transport the goods,[14] 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, $\left(p_{ij}(\varphi) - t_{ij}(\varphi) \right) q_{ij}(\varphi) \geq V_{Ex,ij}(\varphi)$ 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:

$$t_{ij}(\varphi) = \frac{1}{q_{ij}(\varphi)} \left[\eta \left(\psi_{ij} + V_{C,ij} \right) + (1-\eta) \left(p_{ij}(\varphi) q_{ij}(\varphi) - V_{Ex,ij}(\varphi) \right) \right] \tag{A.32}$$

where the transport price is increasing in the cost of providing transport services (ψ_{ij}), the exporter's relative bargaining power (η), 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.[15]

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

$$rV_{Ex,i}(\varphi, \tilde{\varphi}_{ij}) = \rho \zeta_{ij}(\tilde{\varphi}_{ij}) \max \left\{ \left[\left(p_{ij}(\varphi) - t_{ij}(\varphi) \right) q_{ij}(\varphi) - V_{Ex,ij}(\varphi) \right], 0 \right\} \tag{A.33}$$

where the probability of meeting a carrier is $\rho \zeta(\tilde{\varphi}_{ij})$ and the exporter's total profit from ex-

[14] 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.

[15] $\frac{\partial t_{ij}(\varphi)}{\partial q_{ij}(\varphi)} = \frac{(1-\eta) V_{Ex,ij}(\varphi) - \eta(\psi_{ij} + V_{C,ij})}{q_{ij}(\varphi)^2}$.

porting is the difference between its export revenue and transport cost, $\left(p_{ij}(\varphi) - t_{ij}(\varphi)\right) q_{ij}(\varphi)$.[16]

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

$$rV_{C,ij}(\tilde{\varphi}_{ij}) = \rho(1 - \zeta_{ij}(\tilde{\varphi}_{ij}))E_F\left[\max\left\{\left[t_{ij}(\varphi)q_{ij}(\varphi) - \psi_{ij} - V_{C,i}\right], 0\right\}\right] \tag{A.34}$$

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 (A.32), the exporter value function from (A.33) as well as the the carrier's value function from (A.34) can be re-written as

$$\begin{aligned} rV_{Ex,ij}(\varphi, \tilde{\varphi}_{ij}) &= \rho\zeta_{ij}(\tilde{\varphi}_{ij})\eta \max\left\{\left[p_{ij}(\varphi)q_{ij}(\varphi) - V_{Ex,ij}(\varphi) - \psi_{ij} - V_{C,ij}\right], 0\right\} \\ rV_{C,ij}(\tilde{\varphi}_{ij}) &= \rho(1 - \zeta_{ij}(\tilde{\varphi}_{ij}))(1-\eta)E_G\left[\max\left\{\left[p_{ij}(\varphi)q_{ij}(\varphi) - V_{Ex,ij}(\varphi) - \psi_{ij} - V_{C,ij}\right], 0\right\}\right] \end{aligned} \tag{A.35}$$

The exporter's value function $V_{Ex,i}(\varphi, \tilde{\varphi}_{ij})$ is increasing in its productivity φ 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 $\tilde{\varphi}_{ij}$:

$$p(\tilde{\varphi}_{ij})q(\tilde{\varphi}_{ij}) - V_{Ex,ij}(\tilde{\varphi}_{ij}, \tilde{\varphi}_{ij}) - \psi_{ij} - V_{C,ij}(\tilde{\varphi}_{ij}) = 0 \tag{A.36}$$

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 (A.36) also determines the carrier's value function for one direction of a round trip

[16]Since exporters have already produced their goods before searching for a carrier, their search value function does not include production costs of their goods.

from i to j:

$$V_{C,ij}(\tilde{\varphi}_{ij}) = p(\tilde{\varphi}_{ij})q(\tilde{\varphi}_{ij}) - \psi_{ij} \equiv R_{ij} \tag{A.37}$$

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:[17]

$$\zeta_{ij}(\tilde{\varphi}_{ij})\rho M_{Ex,ij} = \rho(1 - \zeta_{ij}(\tilde{\varphi}_{ij}))M_{C,ij} \tag{A.38}$$

B.5.4 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 φ have to pay to ship their goods to destination j. In this model, transport cost is modeled as the only trade barrier.[18] Each exporter draws a random unit of productivity φ. 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 φ 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

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

[18] The endogenous transport cost generates the fixed cost to export since it has a fixed cost to provide transport ψ_{ij}.

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 φ in country i selling to country j is as follows:

$$\max_{p_{ij}(\varphi)} \pi_{ij}(\varphi) = \underbrace{V_{Ex,ij}(\varphi, \tilde{\varphi}_{ij})}_{\substack{\text{Surplus from exporting} \\ \text{if search is successful}}} - \underbrace{c_{ij}(\varphi) q_{ij}(\varphi)}_{\substack{\text{Production cost regardless} \\ \text{of search outcome}}} \tag{A.39}$$

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:

$$c_{ij}(\varphi) \equiv \frac{w_i}{\varphi} \tag{A.40}$$

B.5.5 Exporter entry decision

The entry condition in equation (A.36) 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:

$$\pi(\bar{\varphi}_{ij}) = 0 \rightarrow V_{Ex,ij}(\bar{\varphi}_{ij}, \tilde{\varphi}_{ij}) = c_{ij}(\bar{\varphi}_{ij}) q_{ij}(\bar{\varphi}_{ij}) = \frac{w_i}{\bar{\varphi}_{ij}} q_{ij}(\bar{\varphi}_{ij}) \tag{A.41}$$

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

B.5.6 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:

$$V_{C,ij}(\tilde{\varphi}_{ij}) + V_{C,ji}(\tilde{\varphi}_{ij}) \geq 0 \tag{A.42}$$

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

$$M_{C,ij} = M_{C,ji} \tag{A.43}$$

B.5.7 Solving for the Equilibrium

For the tradeable good, the solution to the consumer's problem in (A.31) takes the CES form:

$$q_{ij} = \left[\frac{\sigma}{\sigma - 1} \frac{1}{a_{ij}} p_{ij} \right]^{-\sigma} \tag{A.44}$$

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 (A.35), conditional on its productivity being above the search threshold $\tilde{\varphi}_{ij}$, can be rewritten as:

$$V_{B,i}(\varphi, \tilde{\varphi}_{ij}) = \frac{\rho\eta\zeta_{ij}(\tilde{\varphi}_{ij})}{r + \rho\eta\zeta_{ij}(\tilde{\varphi}_{ij})} \left[p_{ij}(\varphi) q_{ij}(\varphi) - \psi_{ij} - R_{ij} \right], \text{ for } \varphi \geq \tilde{\varphi}_{ij} \tag{A.45}$$

By inserting the rewritten exporter's value function from (A.45) into the transport price bargaining outcome in (A.32), the following can be shown:

$$t_{ij}(\varphi) = \frac{1}{q_{ij}(\varphi)} \left[\psi_{ij} + R_{ij} + \frac{r(1-\eta)}{r + \rho\zeta_{ij}(\tilde{\varphi}_{ij})\eta} \left[\left(p_{ij}(\varphi) q_{ij}(\varphi) - \psi_{ij} - R_{ij} \right) \right] \right], \text{ for } \varphi \geq \tilde{\varphi}_{ij} \tag{A.46}$$

Holding the search cost ρ 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 φ ($\frac{\partial p(\varphi)q(\varphi)}{\partial \varphi} \geq 0$) 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 ζ_{ij} is solved for by substituting the new exporter value function in (A.45) into the carrier's value function in (A.35)

$$\zeta_{ij}(\tilde{\varphi}_{ij}) = \frac{\rho(1-\eta)E_G\left[p_{ij}(\varphi)q_{ij}(\varphi) - \psi_{ij} - R_{ij}\right] - r(R_{ij})}{\rho\left[\eta R_{ij} + (1-\eta)E_G\left[p_{ij}(\varphi)q_{ij}(\varphi) - \psi_{ij} - R_{ij}\right]\right]} \tag{A.47}$$

where $E_G\left[p_{ij}(\varphi)q_{ij}(\varphi) - \psi_{ij} - R_{ij}\right] = \int_{\tilde{\varphi}_{ij}}^{\infty} p_{ij}(\varphi)q_{ij}(\varphi) - \psi_{ij} - R_{ij}\, dG(\varphi)$. 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 (A.42), the number of carriers will match the number of exporters who choose to enter from condition (A.36).

The optimal export profit-maximizing price $p_{ij}(\varphi)$ from (A.39) is a constant mark-up over unit cost of production plus a transport cost of the iceberg form T_{ij}:

$$\begin{aligned} p_{ij}(\varphi) &= \frac{\sigma}{\sigma-1}\frac{w_i}{\varphi}\frac{r+\rho\zeta_{ij}(\tilde{\varphi}_{ij})\eta}{\rho\zeta_{ij}(\tilde{\varphi}_{ij})\eta\left(r+\rho\zeta_{ij}(\tilde{\varphi}_{ij})\right)} \\ &\equiv \frac{\sigma}{\sigma-1}\frac{w_i}{\varphi}T_{ij}(\tilde{\varphi}_{ij}) \end{aligned} \tag{A.48}$$

Since ρ, ζ_{ij}, η, and r are all fractions respectively, $T_{ij}(\tilde{\varphi}_{ij}) > 1$.[19]

The export price for goods from country i to j is increasing in local wages w_i, decreasing in the exporter's productivity φ, 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 η relative to the carrier decreases $\eta \to 0$, the transport price increases $T_{ij} \to \infty$ as does the export price $p_{ij} \to \infty$.

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

$$\begin{aligned} \pi_{ij}(\varphi) &= \frac{\rho\zeta_{ij}(\tilde{\varphi}_{ij})\eta\left(r+\rho\zeta_{ij}(\tilde{\varphi}_{ij})\right)}{r+\rho\zeta_{ij}(\tilde{\varphi}_{ij})\eta}\left[p_{ij}(\varphi)q_{ij}(\varphi) - R_{ij} - \psi_{ij}\right] - \frac{w_i}{\varphi}q_{ij}(\varphi) \\ &= \frac{1}{T_{ij}(\tilde{\varphi}_{ij})}\left[p_{ij}(\varphi)q_{ij}(\varphi) - R_{ij} - \psi_{ij}\right] - \frac{w_i}{\varphi}q_{ij}(\varphi) \end{aligned} \tag{A.49}$$

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 (ψ_{ij}) will increase exporter profits. An increase in the export revenue ($p_{ij}(\varphi)q_{ij}(\varphi)$) will also increase profits.

[19] Since $\eta < 1$, $r > \eta r \to r + \rho\zeta_{ij}\eta > \eta r + \rho\zeta_{ij}\eta \to \frac{r+\rho\zeta_{ij}\eta}{\eta\rho\zeta_{ij}\eta} > 1$.

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 (A.45)) to the cost of production that they pay for regardless of the search outcome. This means that the exporter earns zero profit in equation (A.39):[20]

$$\begin{aligned}\pi_{ij}(\bar{\varphi}_{ij}) = 0 \rightarrow V_{Ex,ij}(\bar{\varphi}_{ij}, \bar{\varphi}_{ij} = \tilde{\varphi}_{ij}) = c_{ij}(\bar{\varphi}_{ij}) q_{ij}(\bar{\varphi}_{ij}) \\ \bar{\varphi}_{ij} = \lambda_1 \left[\frac{R_{ij} + \psi_{ij}}{a_{ij}^{\sigma}}\right]^{\frac{1}{\sigma-1}} w_i T_{ij}(\bar{\varphi}_{ij})\end{aligned} \tag{A.50}$$

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 (ψ_{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

(i) Quantity q_{kl} satisfies the consumer utility function in (A.31),

(ii) Value functions $V_{Ex,kl}$ and $V_{C,kl}$ satisfy (A.35),

(iii) Transport price $t_{kl}(\varphi)$ satisfies the bargaining outcome in (A.32),

(iv) Price of traded goods $p_{kl}(\varphi)$ satisfies the exporter's profit function in (A.39),

[20] Constant $\lambda_1 \equiv \left[\frac{\sigma}{\sigma-1}^{-2\sigma} \frac{1}{\sigma-1}\right]^{\frac{1}{\sigma-1}}$

(v) The productivity of the marginal exporters $\bar{\varphi}_{kl}$ is given by (A.50),

(vi) The stock of carriers between k and l are the same ($M_{C,kl} = M_{C,lk}$ from (A.43)), and

(vii) The flow of carriers and exporters satisfies the market clearing condition in (A.38)

Aggregate trade flows from i to j is a share of the total expenditure on goods in country j, which is as follows:[21]

$$\begin{aligned} X_{ij}(\bar{\varphi}_{ij}) &= \int_{\bar{\varphi}_{kj}}^{\infty} p_{ij}(\varphi) q_{ij}(\varphi) dG(\varphi) \\ &= \lambda a_{ij}^{\frac{\sigma\gamma}{\sigma-1}} \left(R_{ij} + \psi_{ij}\right)^{1-\frac{\gamma}{\sigma-1}} \left(w_i T_{ij}(\bar{\varphi}_{ij})\right)^{-\gamma} \end{aligned} \tag{A.51}$$

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 (ψ_{ij}) will decrease aggregate flows.

B.5.8 Comparative Statics

One of the main theoretical results in Proposition 1 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 baseline results 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.

Specifically, Lemma 1 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). Similarly, this model shows that an increase in the origin country's tariff will decrease its exports to the

[21] Constant $\lambda \equiv \frac{\sigma}{\sigma-1}^{1+\frac{2\sigma\gamma}{1-\sigma}} \frac{1}{\sigma-1}^{\frac{\gamma}{\sigma-1}-1} \frac{\gamma}{\gamma-(\sigma-1)}$.

same partner. Inversely, an increase in its preference for goods from its partner will also increase its exports to the same partner.[22]

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 (A.44)). Since this also increases the revenue from exporting to country j which increases aggregate trade value X_{ij} (equation (A.51)), 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 (A.43)). 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 (A.38), this increases the matching probability between exporters and carriers from j to i: $\frac{\partial \zeta_{ji}}{M_{C,ji}} > 0$.[23] As a result, the transport price from j to i decreases ($\frac{\partial T_{ji}}{\zeta_{ji}} < 0$, equation (A.48)).[24] In turn, the export quantity and value from j to i increases while the export price falls.[25] The following lemma can be shown:[26]

Lemma 5. *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.*

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

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

[22]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.

[23] $\frac{\partial \zeta_{ji}}{M_{C,ji}} = \frac{1}{M_{Ex,ji}} > 0$

[24] $\frac{\partial T_{ji}}{\zeta_{ji}} = -\frac{\rho^2 \zeta_{ji}^2 \eta + \left(r^2 + 2\rho\zeta_{ji}\right)}{\zeta_{ji}\left(r + \rho\zeta_{ji}\right)} < 0$

[25] $\frac{\partial p_{ji}}{T_{ji}} > 0$, $\frac{\partial q_{ji}}{T_{ji}} < 0$, and $\frac{\partial X_{ji}}{T_{ji}} < 0$.

[26]See Section B.5.9 for proof.

in (A.39) as such:

$$\max_{p_{ij}(\varphi)} \pi_{ij}(\varphi) = \rho\zeta_{ij}(\varphi, \tilde{\varphi}_{ij}) \left(p_{ij}(\varphi) - t_{ij}(\varphi)\right) q_{ij}(\varphi) - \tau_{ij} c_{ij}(\varphi) q_{ij}(\varphi) \tag{A.52}$$

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 $\tau_{ij} > 1$.[27] 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 (A.44)).[28] Since this then decreases the revenue from exporting to country j (X_{ij}, equation (A.51)), 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 (A.43)). From (A.38), this decreases the matching probability between exporters and carriers from j to i: $\frac{\partial \zeta_{ji}}{M_{C,ji}} > 0$. As a result, the transport price from j to i increases ($\frac{\partial T_{ji}}{\zeta_{ji}} < 0$, equation (A.48)). The export quantity and value from j to i falls while price increases. The following lemma can be shown:[29]

Lemma 6. *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 partner will increase while its export*

[27] 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.

[28] Since $p_{ij}(\varphi) = \frac{\sigma}{\sigma-1} \frac{w_i \tau_{ij}}{\varphi} \frac{r+\rho\zeta_{ij}(\tilde{\varphi}_{ij})\eta}{\rho\zeta_{ij}(\tilde{\varphi}_{ij})\eta\left(r+\rho\zeta_{ij}(\tilde{\varphi}_{ij})\right)} \equiv \frac{\sigma}{\sigma-1} \frac{w_i \tau_{ij}}{\varphi} T_{ij}(\tilde{\varphi}_{ij})$, $\frac{\partial p_{ji}}{\tau_{ij} < 0}$.

[29] Section B.5.9 for proof.

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 3. *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.5.9 Proofs

Proof of Lemma 5 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 (A.44)). Since in turn increases the export revenue from country i to j which increases the route's aggregate trade value X_{ij} (equation (A.51)). 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 (A.43)). 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 (A.38), the matching probability between exporters and carriers from j to i now increases:

$$\frac{\partial \zeta_{ji}}{M_{C,ji}} = \frac{1}{M_{Ex,ji}} > 0 \tag{A.53}$$

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:

$$\frac{\partial T_{ji}}{\zeta_{ji}} = -\frac{\rho^2 \zeta_{ji}^2 \eta + \left(r^2 + 2\rho\zeta_{ji}\right)}{\zeta_{ji}\left(r + \rho\zeta_{ji}\right)} < 0 \tag{A.54}$$

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 6 When country j increases its tariffs on goods from country i (τ_{ij}), it is intuitive that its import price p_{ij} should increase which will lead to a fall in quantity q_{ij} (equation (A.44)). Since an export price increase will decreases the overall export revenue from country i to j (X_{ij}, equation (A.51)), 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 (A.43)).

From (A.38), this decreases the matching probability between exporters and carriers from j to i:

$$\frac{\partial \zeta_{ji}}{M_{C,ji}} = \frac{1}{M_{Ex,ji}} > 0 \tag{A.55}$$

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:

$$\frac{\partial T_{ji}}{\zeta_{ji}} = -\frac{\rho^2 \zeta_{ji}^2 \eta + \left(r^2 + 2\rho\zeta_{ji}\right)}{\zeta_{ji}\left(r + \rho\zeta_{ji}\right)} < 0 \tag{A.56}$$

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