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What Goes Around Comes Around: Export-Enhancing Effects of Import-Tariff Reductions*

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Abstract

In international trade, transportation requires a round trip for which a transport firm has to commit to shipping capacity that is sufficient to meet the maximum shipping volume. This may cause the "backhaul problem." Trade theory suggests that, facing the problem, transport firms with market power adjust their freight rates strategically when import tariffs change. As a consequence, a country reducing its import tariffs may experience an increase in exports as well as imports. Using worldwide data covering 1995-2007, we find evidence that supports these predictions: a 1% reduction in an importer's tariffs increases the import freight rates by around 0.8%; decreases the export freight rates by around 1.1%; and increases the export quantity by 0.6% to 1%. These findings indicate a new mechanism through which import-tariff reductions lead to export expansions.

JEL Codes: F12, F13, R40

Key words: Transport firm; freight rates; tariffs; backhaul problem

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1. Introduction

While it is obvious that a country's import tariffs affect its domestic imports, they may also affect the country's exports. Existing studies identify a few channels through which domestic import tariffs affect domestic exports. Early studies indicate a negative effect of import liberalization on exports: for example, restricting imports could enhance exports when the protected industry exhibits increasing returns to scale (Krugman, 1984). However, more recent studies identify positive effects of reducing import restrictions on exports. Global supply chains and associated vertical trade could explain the following positive effects: a country that lowers its import tariffs on intermediate inputs may lead to lower production costs, thereby increasing its exports of final goods.[1]

The nature of international transportation points to another channel through which import tariffs may influence domestic exports. By constructing a trade model with an explicit transport sector, Ishikawa and Tarui (2018) demonstrate theoretically that an increase in domestic import tariffs may decrease domestic exports. Their model incorporates a transport sector with market power,[2] where asymmetric transport pricing is allowed.[3] In particular, they take the backhaul problem into account explicitly in their model. Carriers have to commit to sufficient shipping capacity to meet the maximum shipping volume, which may result in the backhaul problem, i.e., an imbalance in shipping volume in two directions. Profit-maximizing transport firms would adjust their shipping capacity and freight rates to avoid the backhaul problem as much as possible.[4]

With this model, Ishikawa and Tarui (2018) show that an increase in domestic import tariffs reduces domestic exports when a transport firm, subject to its capacity constraints on shipping, responds to policy changes by adjusting its freight rates charged on shipping in both directions and its capacity level. This result holds with

[1] By using Indonesian firm-level data, Amiti and Konings (2007) find that a reduction in import tariffs on inputs leads to a productivity gain by the firms in the sectors that import these inputs. This might indicate that these firms may in turn increase their exports.

[2] Hummels et al. (2009) find empirical evidence of market power with container shipping by demonstrating that goods with higher product prices, lower import demand elasticities, higher tariffs, and when facing fewer competitors on a trade route are charged higher transport prices.

[3] As evidence of asymmetric pricing, the market average freight rates for shipping from Asia to the United States were approximately 1.5 times the rates for shipping from the United States to Asia in 2009 (United Nations Conference on Trade and Development, 2010).

[4] Dejax and Crainic (1987) provide an early survey of the research on backhaul problems in transportation studies.

oligopolistic transport firms even when the trade volume is not balanced at the aggregate level.[5]

The purpose of this paper is to empirically test Ishikawa and Tarui's (2018) theoretical predictions about the effect of import tariffs on domestic exports through the new channel. Specifically, by exploiting variations in tariff rates across countries and over time, we examine how freight rates between two countries are related to their respective tariff rates. We apply data on freight rates from the Maritime Transport Costs database published by the Organisation for Economic Co-operation and Development (OECD) and tariffs from the World Integrated Trade Solution (WITS). Our sample for estimation includes bilateral freight rates and tariffs for 137 export countries and 10 import countries during 1995-2007. We focus on freight rates in transporting products subject to containerized trade because containerized ocean transportation is consistent with the above theoretical setting. We regress the container freight rates on both exporter's and importer's tariff rates for products shipped by containers.

However, there may be some sources of endogeneity bias in our tariff variables. For example, a policy to facilitate trade between two countries may include not only tariff reduction but also transport facilitation. In addition, there may be some mechanisms through which a change in freight rates triggers a tariff reform. As explained in Section 3.2, our tariff variables also suffer from the measurement error problem. To address these endogeneity problems, we use the instrumental variable (IV) method. Specifically, we use tariff rates for products shipped by dirty-bulk and tankers as instruments. Since the broad trade policy is determined at the national level, tariffs on products shipped by dirty-bulk and tankers are likely to have correlation with tariffs on those shipped by containers. Furthermore, we argue that dirty-bulk and tanker tariffs do not have direct impacts on container freight rates. To assure the validity of the exclusion restriction further, we control for fixed effects defined at a detailed level.

Our use of worldwide data implies strong external validity of our results. It also increases the sample size relative to studies focusing on a bilateral or regional trade and thus raises the statistical power of our results. By contrast, our results may be weak in terms of internal validity, compared with well-identified case-specific studies such as those using natural experiments (e.g., Feyrer, 2009). Indeed, there may be unobservable elements that affect both container freight rates and dirty-bulk tariffs but cannot be controlled for by a set of our fixed effects. For example, a trade-facilitation policy that incorporates not only tariff reduction but also transport

[5] The concern here is not the balance in trade value, but the balance in trade volume. Therefore, the Lerner Symmetry Theorem is not relevant to this result.

facilitation may result in lowering both container freight rates and dirty-bulk tariffs. The existence of such elements results in violating the exclusion restriction of our instruments. Nevertheless, this study contributes to the empirical trade literature by proposing new instruments with an advantage that they are relevant to most trade flows and years and have stronger external validity compared with natural experiments.

Our preferred IV estimates indicate that a reduction of home import tariff rates lowers the freight rates on home exports, supporting the theoretical prediction described above. Specifically, a 1% increase in an importer's tariffs reduces the import freight rates by around 0.8% and increases the export freight rates by around 1.1%.[6] This finding is robust under several alternative specifications of the econometric model. In addition, we empirically examine the relationship between exports and tariff rates. A decrease in freight rates on the exports to a trading partner, driven by lower import tariffs, obviously increases export volume to the partner. To investigate this consequence on trade volume, we estimate gravity equations for the worldwide trade quantities by introducing not only own country's tariffs but also a partner's tariffs. We find that a country's export quantity increases when its import tariff rates decrease.

Most trade models assume away transport costs or treat them in an ad hoc manner (e.g., the usual iceberg cost specification, Samuelson 1952). In particular, the transport costs are often assumed to be exogenous and symmetric. However, studies surveyed by Behar and Venables (2011) show that freight costs have a statistically significant and quantitatively important impact on trade flows. Transport costs particularly pose a barrier to international trade that is often higher than tariffs (Hummels, 2007). An estimate suggests that transportation costs and trade barriers (i.e., tariffs and non-tariff barriers) account for 21% and 7.7%, respectively, of representative trade costs for industrialized countries (Anderson and van Wincoop, 2004).

Several recent studies address related linkages among trade, trade policy (e.g., tariffs), and freight rates. For example, Asturias (2016) studies endogenous costs of containerized shipping through oligopolistic competition among transport firms. However, the study does not consider the backhaul problem or capacity constraints faced by transport firms. As a result, neither the theory nor the policy experiments capture the export-enhancing effects of import-tariff reductions. Similarly, Boddin and Stähler (2018) focus on the direct impact of import tariffs on the shipping costs of

[6] As discussed in Section 4.1, this estimate is within the range of values that a back-of-the-envelope computation based on the theory, along with trade-related elasticity estimates in the recent literature, indicates.

imports but not on those of exports; Brancaccio et al. (2020) examine the role of import freight costs of the flow of imports. In short, these studies empirically examined the relationship among trade, trade policy, and freight rates in the same direction of trade flow (i.e., imports, import tariffs, and freight rates on imports).

A significant departure point of our study is to test whether import tariffs affect exports and shipping costs of exports. Wong (2018) addresses a similar research question but with a different theoretical model and empirical strategies. Wong's regression analysis takes the freight rate as a regressor to predict U.S. trade flows. The estimated elasticity of demand with respect to freight rates (in addition to some calibrated parameters) is then applied to her theoretical model, which assumes competitive transport firms and no backhaul problems (i.e., balanced trade). The counterfactual exercise based on this model predicts the effect of hypothetical increases in the U.S. tariff rates. By contrast, we apply worldwide data on freight rates, tariff rates, and trade to estimate directly how freight rates depend on variations in observed tariff rates. In sum, Wong (2018) and our study are complementary.[7]

In what follows, we present a theoretical framework that explains the effects of trade liberalization on freight costs and trade quantities in Section 2. Section 3 summarizes the empirical framework that we employ to test the theory by using data on trade and transport costs. Section 4 presents our main empirical results, as well as a few extensions that address their robustness. Section 5 concludes.

2. Conceptual Framework

Our theoretical framework relies on the trade model with an explicit transport sector developed by Ishikawa and Tarui (2018). In particular, they consider the following characteristics of international (containerized) shipping when constructing their model: (i) market power in the transport sector, (ii) asymmetric freight rates among directions, (iii) transport pricing subject to the backhaul problem, and (iv) linear pricing or additive transport costs.[8] In the following, we briefly explain their

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[7] Another related study is Friedt and Wilson (2015) that simulate how China's complete ban of waste imports from the United States affects the freight costs charged on Chinese imports and exports.

[8] Using multi-country bilateral trade data at the six-digit HS classification, Hummels and Skiba (2004) find that shipping technology for a single homogeneous shipment more closely resembles per unit, rather than ad valorem, transport costs. Using Norwegian data on quantities and prices for exports at the firm/product/destination level, Irarrazabal et al. (2015) find the presence of additive (as opposed to iceberg) trade costs for a large majority of product-destination pairs.

basic model that is tailored to derive our testable hypotheses but maintains the four key features stated above.

Consider trade between two countries A and B. Country $A(B)$ exports good $A(B)$ and imports good $B(A)$. The markets of goods A and B are perfectly competitive. Country i (i=A,B) sets an ad valorem import tariff. A monopolistic firm provides transport services, which are required for trade between the two countries. Thus, when exporting the good, each firm faces an ad valorem import tariff imposed by the other country as well as freight rates charged by the monopolistic transport firm. The assumption of the monopolistic transport firm is not extreme. Hummels et al. (2009) observe from 2006 data that one in six importer-exporter pairs worldwide was served by a single direct liner "service," meaning that only one ship was operating on that route. They also state that "[o]ver half of importer-exporter pairs were served by three or fewer ships, and in many cases all of the ships on a route were owned by a single carrier." Ishikawa and Tarui (2018) find that the main result presented here holds when there are more than one transport firms with market power.[9]

Suppose the inverse export supply of a good from country i to j, S_i, satisfies

$$p_i = S_i(X_{ij}),$$

where p_i is the price that the producers receive, X_{ij} the quantity of export from country i to j, and $S_i' > 0$. The (inverse) import demand for the good in country j is given by

$$p_i(1+\tau_j) + T_{ij} = D_j(X_{ij}),$$

where T_{ij} is the freight rate for shipping from country i to j, τ_j the tariff rate set by country j, and $D_j' < 0$. This specification follows the empirical findings that the transport costs, unlike import tariffs, are additive. From these two equations we have a condition for the market equilibrium:

$$S_i(X_{ij})(1+\tau_j) + T_{ij} = D_j(X_{ij}).$$

Solve this equation for the demand for transportation of the good from country i to j:

$$X_{ij} = \phi^{ij}(T_{ij}, \tau_j).$$

A monopolistic transport firm's costs of shipping, C, are given by

$$C = f + rk,$$

[9] Specifically, the result holds even when the trade volume between two countries is not balanced as long as at least one transport firm avoids the backhaul problem. For the ease of exposition, we present a model with a monopolistic transport firm here. Friedt and Wilson (2015) present a similar model with n oligopolistic transport firms, but consider only two equilibria (one where the trade volume is balanced for each firm and the other where the trade volume is not balanced for each firm). As Ishikawa and Tarui (2018) demonstrate in their oligopolistic model, any number of transport firms between 1 and n may be associated with balanced shipping. A complete characterization of all possible equilibria thus requires lengthy discussions.

where r, f, and k are, respectively, the marginal cost of operating a means of transport such as vessels, the fixed cost, and the shipping capacity such that

$$k = \max\{X_{ij}, X_{ji}\}.$$

The transport firm chooses the shipping capacity k and the freight rates T_{ij} and T_{ji} (for each route (i, j)) in order to maximize its profit:

$$\Pi_T = T_{ij}\phi^{ij}(T_{ij}, \tau_j) + T_{ji}\phi^{ji}(T_{ji}, \tau_i) - rk,$$

where the shipping quantity is constrained by the capacity.

The backhaul problem arises if either $X_{ij} < X_{ji} = k$ or $X_{ji} < X_{ij} = k$ holds. We focus on the case in which the transport firm avoids the backhaul problem (i.e., $X_{ji} = X_{ij} = k$). If $X_{ij} = X_{ji} = k$ holds, then the transport firm solves the profit maximization problem subject to $\phi^{ij}(T_{ij}, \tau_j) = \phi^{ji}(T_{ji}, \tau_i)$. In this case, the equilibrium shipping quantity, X^*_{ij}, is decreasing in both τ_j and τ_i:

$$\frac{\partial X^*_{ij}}{\partial \tau_i} < 0, \qquad \frac{\partial X^*_{ij}}{\partial \tau_j} < 0. \tag{1}$$

It also follows that the equilibrium freight rates depend on the tariff rates in the following manner (see Appendix A):

$$\frac{\partial T^*_{ij}}{\partial \tau_i} > 0, \qquad \frac{\partial T^*_{ij}}{\partial \tau_j} < 0. \tag{2}$$

Therefore, country j's tariff necessarily increases the freight rate from country j to country i and decreases country j's exports.

The mechanism of the export-enhancing effect of an import-tariff reduction is as follows: a country's import-tariff reduction induces the transport firm to raise the freight rate on the import (thus partially offsetting the effect of tariff reduction). Because the increase in the freight rates only partially offset the tariff reduction, the import quantity increases. When the trade volume is balanced,[10] the transport firm lowers the freight rate on exports in order to avoid the backhaul problem. This results in an increase in exports by the country (Ishikawa and Tarui, 2018, Proposition 2). Their paper subsequently illustrates that this finding is robust when there are multiple output sectors (Proposition 7) and when there are multiple, oligopolistic transport firms (Proposition 6). In these extensions, balanced trade volume is not necessarily required for the export-enhancing effects of tariff reductions to be present.

In what follows, we investigate the following testable hypotheses based on Ishikawa and Tarui's (2018) results as summarized in inequalities (1) and (2):

Hypothesis 1. *A tariff reduction by a country tends to reduce the freight rate for shipping from the country.*

[10] Our concern is not the balance in trade value, but trade balance in volume.

Hypothesis 2. *A tariff reduction by a country tends to increase the country's exports (in addition to the country's imports).*

Regarding Hypothesis 1, we can describe the magnitude of the effect of a change in tariffs on the freight rate. Appendix A derives the following expression for the elasticity of freight rates T_{ji} with respect to tariff τ_j:

$$\frac{\partial T_{ji}}{\partial \tau_j}\frac{\tau_j}{T_{ji}} = \frac{\tau_j}{T_{ji}/p_i} \cdot \frac{\left(1+\frac{1}{\varepsilon_S^i}\right)\eta^{ij}\frac{\phi^{ij}}{T_{ij}}}{\eta^{ij}\left(2-\varepsilon^{ji}\right)\frac{\phi^{ij}}{T_{ij}} + \eta^{ji}\left(2-\varepsilon^{ij}\right)\frac{\phi^{ji}}{T_{ji}}},$$

where $\eta^{ij} \equiv \frac{\partial X_{ij}}{\partial T_{ij}}\frac{T_{ij}}{X_{ij}}$ is the elasticity of shipping with respect to the freight rate (or the trade cost elasticity); $\varepsilon^{ij} \equiv \phi^{ij}\phi_{TT}^{ij}/\left(\phi_T^{ij}\right)^2$ represents the elasticity of the slope of the inverse demand curve for shipping from i to j; and $\varepsilon_S^i \equiv S_i/\left(\phi^{ij}S_i'\right)$ the price elasticity of excess supply from country i. The first fraction on the right-hand side indicates that $\frac{\partial T_{ji}}{\partial \tau_j}\frac{\tau_j}{T_{ji}}$ is increasing in the tariff rate relative to the freight rate as the share of the product price. It also follows from the second fraction that $\frac{\partial T_{ji}}{\partial \tau_j}\frac{\tau_j}{T_{ji}}$ is increasing in the inverse export supply elasticity: the more elastic the export supply, the smaller the freight rate adjustment.

We can assess the approximate values by applying some off-the-shelf estimates of various elasticity measures from the literature and by making some simplifying assumptions. Assume that $\eta^{ij} \approx \eta^{ji}$ and $\phi^{ij}/T_{ij} \approx \phi^{ji}/T_{ji}$. Then

$$\frac{\partial T_{ji}}{\partial \tau_j}\frac{\tau_j}{T_{ji}} \approx \frac{\tau_j}{T_{ji}/p_i} \cdot \frac{1+\left(1/\varepsilon_S^i\right)}{\left(2-\varepsilon^{ji}\right)+\left(2-\varepsilon^{ij}\right)}.$$

The average tariff rate in our sample (discussed below in detail) is 6%, while the transportation costs (measured by cif-fob trade ratio) averaged at about 4% in 1986-1988 according to the estimates by Baier and Bergstrand (2001). With these estimates, the first term on the right-hand side is equal to 1.5. Recent estimates of trade elasticity η are around -4.[11] Assuming that this value applies for both countries i and j, we have

[11] Simonovska and Waugh (2014) provide estimates of trade elasticity based on a structural approach that corrects for potential bias in earlier estimates, with a central estimate of about -4. Bas et al. (2017) provide estimates of about 4 at the intensive margin (or at the firm level) and between -2.5 and -5 at the aggregate level. Whereas the trade elasticity in the literature refers to that of imports relative to domestic demand, the elasticity defined in our paper does not consider changes in domestic demand.

$\varepsilon^{ji} = \varepsilon^{ij} \approx 0.83$. [12] Broda et al. (2008) report a median of inverse export supply elasticities (sectoral at HS4 level) over 15 countries in their sample at 0.4 (low) to 3.4 (medium to high, Table 3B). These values indicate that a percent increase in a country's import tariff rate would lead to a 0.9% to 2.83% increase in the freight costs of the country's exports on average. The analytical expression above applies to the case with a monopolistic transport firm and balanced shipping. Ishikawa and Tarui (2018) show that the elasticity is positive in the case with more than one transport firm as long as shipping is balanced for at least one transport firm; and that the magnitude is lower when a transport firm's shipping is unbalanced. These theoretical observations imply that the estimate may be lower than the back-of-the-envelope estimate described here.

3. Empirical Framework

First we present our empirical framework with ordinary least squares (OLS) estimations. Then we explain our identification strategy that addresses potential endogeneity issues associated with the OLS approach.

3.1 OLS Approach and Data

As shown in equation (2), the freight rates depend not only on the importer's tariff rates but also on the exporter's tariff rates. To examine this theoretical prediction, we estimate the following reduced-form equation:

$$\ln Freight_{ijpt} = \gamma_1 \ln\left(1 + Tariff_{ijt}\right) + \gamma_2 \ln\left(1 + Tariff_{jit}\right) + u_{ijp} + u_{ipt} + u_{jpt} + \epsilon_{ijpt},$$

where $Freight_{ijpt}$ represents additive freight rates on the export of product p from country i to country j in year t. The variable $Tariff_{ijt}$ is an average ad-valorem tariff rate on country i's exports to country j in year t. We explain in detail how we construct the tariff variables at the end of this subsection. As demonstrated in the previous section, the coefficients for importer's tariffs (i.e., $Tariff_{ijt}$) and exporter's tariffs (i.e., $Tariff_{jit}$) are expected to be negative and positive, respectively.

To identify the effect of tariffs on the freight rates, we introduce various fixed effects that control for other factors that affect freight rates. Exporter-importer-product fixed effects (u_{ijp}) control for time-invariant country pair-product specific elements,

[12] If we assume utility with constant elasticity of substitution σ across goods, then the trade elasticity is given by $\eta = \sigma - 1$ while the elasticity of the slope of the inverse demand curve ε is given by $\sigma/(\sigma + 1)$. With $\sigma - 1 = 4$, we have $\varepsilon \approx 0.83$.

including costs specific to the freight routes between two countries, in addition to product-specific components of freight rates. For example, freight rates for transporting goods to landlocked countries would contain components that are different from those for transporting goods between two island countries. As in the gravity studies, these fixed effects also control for country-pair specific factors, such as geographical distance, linguistic commonality, and national border sharing. Time-variant export country-product characteristics such as export prices are controlled for by exporter-product-year fixed effects (u_{ipt}).[13] Importer-product-year fixed effects (u_{jpt}) control for time-variant import country-product characteristics such as the product demand size. These time-variant fixed effects also capture the effects of changes in the price of oil, which is a significant cost component of ocean shipping. The last variable ϵ_{ijpt} is the disturbance term.

The data on our main variable, i.e., freight rates, are obtained from the Maritime Transport Costs database published by OECD (Korinek, 2011).[14] It provides the data on freight rates for 43 importing countries (including EU15 countries as a customs union) of origin at the detailed commodity (six-digit) level of the Harmonized System (HS) 1988. Although the database includes not only original customs data but also estimates, we only use the former, which are available for imports by Australia, New Zealand, the United States, Argentina, Brazil, Chile, Colombia, Ecuador, Peru, and Uruguay.[15] Based on the availability of the data on other variables (i.e., tariffs), a total of 57 countries are included as exporters. Our sample covers trade between 1995 and 2007.

We observe data on freight rates only for the countries that have trade relationship because we use freight rates computed based on the actual trade. To reduce the share of missing observations (i.e., combinations with no trade relationship) in all possible combinations, i.e., to mitigate the risk of sample selection bias, we define the product at the HS two-digit level, although the analysis at a finer level enables us to minimize the change of freight rates based on the product mix. We focus on freight rates in transporting products subject to containerized trade (hereafter, container tariffs) because containerized ocean transportation is consistent with our theoretical setting of the transportation sector with market power.[16] As suggested in the empirical literature on transport costs (Hummels and Skiba, 2004; Irarrazabal et

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[13] In Section 4.2, we also consider the case where (fob) export from each country may be priced differently across destinations.

[14] https://stats.oecd.org/Index.aspx?DataSetCode=MTC#

[15] Hummels and Lugovskyy (2006) also use the same data for New Zealand and the United States.

[16] As listed in Korinek (2011), such products include all products except for HS codes 10, 1201-1207, 1507-1514, 25, 26, 2701-2716, 28, 29, 31, 72, 8701-8705, 8716, 8802, and 89. For more details on the Maritime Transport Costs database, see Korinek (2011).

al., 2015), we specify freight rates as additive rates (i.e., freight rates per kilogram) instead of ad valorem.

Another important variable in our analysis is tariff rates. We exploit variations of the average of tariff rates over all commodities subject to containerized trade over time and across country pairs. Just as a container may carry a mixture of products from various sectors, freight rates on a particular manufacturing good may depend not only on the trade volume of the good itself but on the total trade volume between countries. Therefore, we define tariff variables at a country pair-year level rather than at a country pair-product-year level. To compute country-pair level average tariff rates, we use the weighted average in terms of imports at a commodity (HS six-digit) level because freight rates depend on both the prices and the quantities of the delivered goods: the effect of tariff rates on freight rates is larger for products with larger trade volume or values. As the weight, we use the trade data evaluated on the fob basis because freight rates play a key role in our theoretical prediction. Thus, we use trade values that do not include freight rates. Such trade data can be obtained from the BACI database in CEPII.

We constructed our tariff variables in the following manner. First, tariff line-level data on tariff rates are obtained from the WITS database.[17] Second, at the tariff-line level, we identify the lowest tariff rates among all schemes, including not only most favored nation but also regional trade agreements (RTAs) and generalized system of preferences, available for each country pair. Namely, our tariff rates are applied rates. Third, tariff rates at the tariff-line level are converted to those at the six-digit level of HS1988 using the conversion table available on the website of United Nations Statistics Division.[18] We apply the simple average for this aggregation. Finally, we compute the weighted average of tariff rates by using HS six-digit level imports (evaluated at a fob basis) as the weight.[19]

3.2 Endogeneity Issues and Identification Strategy

[17] http://wits.worldbank.org/WITS/

[18] https://unstats.un.org/unsd/trade/classifications/correspondence-tables.asp

[19] The importer-product-year fixed effects control for the change of the most favored nation tariff rates. Hence, our tariff variables in this specification mainly capture the change of tariff rates when RTAs enter into force. Several RTAs entered into force during our sample period. For example, Australia had RTAs with Singapore in 2003 and with the U.S. and Thailand in 2005. Chile had RTAs with the European Free Trade Association and South Korea in 2004 and with Japan and India in 2007. As a result, we still have enough variation in the change of our tariff variables, even after controlling for exporter-product-year and importer-product-year fixed effects.

In the empirical framework above, there are three sources of endogeneity that indicate bias in the OLS estimates. The first is omitted-variable bias. As specified in the previous subsection, we control for various fixed effects. These fixed effects reduce the possibility of failing to control for factors that can affect both tariffs and freight rates in containerized trade. However, there may be unobservable elements that cannot be controlled for by the set of our fixed effects. For example, suppose that a policy to facilitate trade between two countries includes not only tariff reduction but also transport facilitation (e.g., streamlining shipping). Such a policy may lower not only import tariffs but also import freight rates because of transport facilitation. By contrast, if such a policy includes export promotion rather than transport facilitation, it is likely to lead to higher export freight rates because of the increase in exports, in addition to lower import tariffs. Since the set of our fixed effects cannot control for such time-variant country-pair specific elements, the error term in our equation may be correlated with our tariff variables. Specifically, while the former example creates upward bias in the OLS estimates on the effect of importer's tariffs, the latter indicates downward bias in those on the effect of exporter's tariffs. In the presence of these factors, OLS would underestimate the effects of both importer's and exporter's tariffs.

The second source of bias is reverse causality. There may be some mechanisms through which a change in freight rates triggers a tariff reform. For example, a decrease in the import freight rates of a certain product may contribute to the establishment of a global supply chain. To enhance its development, the government may have an incentive to lower the import tariff on that product. This channel generates upward bias in the OLS estimate in the coefficient for the importer's tariffs and leads to an underestimate of its absolute magnitude. Similarly, an increase in the export freight rates may induce firms to supply their products to the foreign markets through foreign direct investment rather than exports. Because this shift reduces production at home, the government may have a lower incentive to maintain high import tariffs. Again, this channel yields downward bias in the OLS estimate in the coefficient for the exporter's tariffs and leads to an underestimate of its absolute magnitude.

The last is the measurement error in our tariff variables. We aggregate country pair-product-level tariffs to the country-pair level by using import values as the weight. However, freight rates may depend on various characteristics of delivered goods, including the number of units, weight, and unit prices, by various degrees. Thus, our use of a single unit of measurement (i.e., import values) as the weight for aggregation may create some errors in our tariff variables, resulting in attenuation bias towards zero.

To address these sources of endogeneity bias, we apply the IV method. Specifically, we use country pair-level tariff rates for products shipped by dirty bulk (hereafter, dirty-bulk tariffs) as instruments.[20] Similar to the container tariffs, dirty-bulk tariffs are constructed as the weighted average of tariff rates among products shipped by dirty bulk. Since the broad trade policy is determined at the national level, the trend of tariffs is likely to be correlated across products. Namely, dirty-bulk tariffs are likely to correlate with container tariffs. In addition, changes in dirty-bulk tariffs do not seem to have direct impacts on container freight rates. This property of dirty-bulk tariffs strengthens the validity of their exclusion restriction. Furthermore, since the products shipped via dirty bulk are different from those shipped by containers, the error component in container tariffs would not be associated with dirty-bulk tariffs and their error component.

One threat to the exclusion restriction is the existence of unobservable elements that affect both container freight rates and dirty-bulk tariffs. As the above discussion about omitted variable bias indicates, our inclusion of fixed effects reduces the possibility of failing to control for such elements. However, there may be some time-variant country pair-specific factors that cannot be controlled for by the set of our fixed effects. For example, the above-mentioned policy of trade facilitation results in lowering both container freight rates and dirty-bulk tariffs. The existence of such factors may violate the exclusion restriction of our instruments.

In sum, given our observations of worldwide trade and inclusion of various levels of fixed effects, we believe that our instruments are rather plausible. Nevertheless, they are not perfect because of the existence of potential elements that violate the exclusion restriction. The validity and limitations of the tanker tariffs as instruments are similar to those of the dirty-bulk tariffs. In some specifications below, we also apply tanker tariff rates as another instrument.

4. Empirical Results

We first report the results of our baseline estimation and then show the findings from additional analyses to evaluate the robustness of the main result. We also examine the effects of tariff rates on trade volume.[21] Since our empirical specification

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[20] Dirty bulk refers to industrial raw materials such as iron ore, coal, and bauxite and is distinct from the products shipped by containers (Korinek, 2011). The corresponding HS codes include 26, 28, 29, 31, 72, 25, 2701-2706, 2712-2716 (Korinek, 2011). Similarly, those shipped by tankers are under HS codes 15 and 27.

[21] Basic statistics of our variables are reported in Table B1 in Appendix B. We exclude products with the top 5% of freight-rate changes over the sample period for each country-pair as outliers.

applies gravity equation, we cluster the standard errors by country pair and product-year by following Egger and Tarlea (2015).

4.1. Baseline Estimation

Table 1 presents our baseline estimation results. Column (I) reports the results of the OLS estimation for the comparison purpose. They are consistent with our theoretical predictions in (2): the coefficients for importer's tariffs and exporter's tariffs are negative and positive, respectively, though the latter is not statistically significant. Columns (II) and (III) show the IV estimation results.[22] In column (II), we use the exporter's and the importer's dirty-bulk tariffs as instruments. In column (III), in addition to the dirty-bulk tariffs, we also use the tanker tariffs as instruments. As is consistent with our expectation, the estimated coefficients for importer's tariffs and exporter's tariffs are negative and positive, respectively, and statistically significant. In both columns (II) and (III), the test statistics for under-identification (KP rk LM statistics) and weak identification (KP rk Wald F statistics) show reasonably high values. The high value in the under-identification test indicates that the rank condition is satisfied and that the equations are identified. The high value in the weak identification test suggests that our IV estimates are unlikely to suffer from bias due to weak instruments. In column (III), Hansen J statistics show that the null hypothesis (that the over-identifying restrictions are valid) is not rejected at a 10% significance level, indicating that the instruments are valid and excluded correctly from the equation.

=== Table 1 ===

Three remarks are in order regarding the magnitude of our estimates. First, the absolute magnitude of the coefficients for both tariffs is much larger in the IV results than in the OLS results. This implies that the OLS estimates are underestimated—consistent with the several possible sources of bias as we pointed out in Section 3.2. Second, column (II) indicates that a 1% increase in our importer's tariff variable reduces import freight rates by 0.86% and increases export freight rates by 1.14%. A 1% increase in our tariff variable is roughly equivalent to a one-percentage point rise

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In addition, observations with abnormally high tariff rates (the top 1%) are excluded. Such products tend to have non-ad-valorem tariffs, which are likely to be transformed to high ad-valorem equivalent rates.

[22] The results in the first stage estimation are reported in Table B2 in Appendix B. All results show that importer's (exporter's) tariffs on dirty-bulk and tanker shipping have significantly positive coefficients when the dependent variable is importer's (exporter's) tariffs for containers.

of tariff rates. We observe that our estimates are within the range of estimates indicated by the theory and off-the-shelf estimates of various elasticities (0.9 to 2.83) as discussed in Section 2. Wong's (2018) simulation, on the contrary, indicates that doubling the U.S. tariffs would decrease the freight rates on U.S. imports by 0.15% and increase those on U.S. exports by 0.18%. Since the sample average of U.S. tariff rates is 1.16%, doubling tariffs roughly means about a one-percentage point increase of tariff rates. As a result, our estimates are approximately six times as large as those in Wong (2018).

One reason for the larger elasticity in our estimates may be that our sample includes many developing countries while Wong (2018) focuses on U.S. trade with the world. Since the U.S. has a large number of export products with large values, the transport firms may be able to absorb demand or supply shocks to a specific product by adjusting the freight rates and the volume of other products. In other words, the backhaul problem can be addressed without reducing freight rates for that specific product substantially. By contrast, because the number of export products is limited in developing countries, the freight rates may need to be adjusted substantially to avoid the backhaul problem. In addition, this difference may be a reason why the absolute magnitude is smaller in importer's tariffs than in exporter's tariffs. Our sample of importing countries are mainly developed countries while the exporting countries include many developing countries in the world.

Lastly, we illustrate the economic significance of our estimates. For example, on average, China's container tariffs on the export from the U.S. decreased by 6% between 2001 and 2007. According to our estimates, this reduction would have increased the freight rates from the U.S. to China by 5.2% (≈ 6 x 0.86) and decreased those from China to the U.S. by 6.8% (≈6 x 1.14). Though these are sizeable impacts, in terms of the goods prices, these adjustments translate to about a 0.2% increase and a 0.3% decrease, respectively.[23] However, the potential welfare gains from freer trade (or trade protection at the optimal tariff levels) associated with 5-10% tariff rate changes are considered to be modest but non-trivial in the literature (Costinot and Rodríguez-Clare, 2014).

4.2. Robustness Checks

We conduct several robustness checks. First, we apply the non-logged version of our tariff variables including instruments instead of their logged version. Although

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[23] Baier and Bergstrand (2001) showed that on average, the transportation costs (measured by cost-insurance-freight (cif)-fob trade ratio) was 8.21% in 1958–1960 and 4.27% in 1986–1988. Based on these numbers, we use 4% as freight costs relative to goods prices.

we specify our empirical model as a log-log model, the theory does not necessarily indicate that freight rates and tariffs should be logged.[24] In addition, although a 1% rise of our tariff variable is roughly equivalent to a one-percentage point rise of tariff rates if tariff rates are small, some products are subject to high tariffs. The estimation results for the non-logged tariffs are reported in columns (IV)-(VI) of Table 1. They are both quantitatively and qualitatively the same as those in columns (I)-(III). Namely, a country's reduction of tariff rates increases the freight rates of its imports but decreases those of its exports.

Second, we restrict the sample to exclude country pairs in which either the importer or the exporter is landlocked.[25] When landlocked countries conduct trade involving ocean shipping, their goods need to pass the national boundary of a third country. Due to the land transport involved, freight rates may be heavily affected by the trade volume between the third country and the landlocked country's trading partner. Although we control for the difference in the level of freight rates across country pairs by applying exporter-importer-product fixed effects, the coefficients for tariff variables may also be different for landlocked countries. To exclude such landlocked-country-specific effects, we use a subsample that excludes observations associated with landlocked countries and focus on countries facing coasts. The results, reported in columns (I)-(III) in Table 2, again show the negative coefficients for importer's tariffs and the positive coefficients for exporter's tariffs though the coefficients for importer's tariffs are insignificant in column (III). For the specification in column (III), the Hansen test is rejected at a 10% significance level, indicating a possibility of misspecification.

=== Table 2 ===

So far we have assumed that (fob) export prices are independent of importing countries and thus can be completely controlled for by export country-product-year fixed effects. This assumption is valid as long as the export markets are perfectly competitive. However, the export prices may be different across destinations when the relevant markets are imperfectly competitive. For example, exporters of differentiated goods may ship goods with higher quality (and thus higher prices) to more distant destinations due to additive freight rates (i.e., the Alchian-Allen hypothesis). Though time-invariant differences in such destination-specific pricing

[24] As shown in Table B1 in Appendix B, the freight rates have large standard deviation. Thus, our preferred specification is log-log in order to address heteroscedasticity.

[25] In the analyses below, we again take log of tariffs though taking logs does not change the results much as found in Table 1.

are captured by the country pair-product fixed effects, pricing across destinations may change over time.

If the export prices differ by country pairs, the coefficients for our tariff variables indicate not only the direct (i.e., the effect based on the backhaul problem) but also indirect effects of tariffs on freight rates through changing the export prices. For example, higher tariffs in the home country decrease the home (fob) import prices (i.e., the foreign (fob) export prices). To the extent that the freight rates are partially ad valorem, the decrease in the home import prices lowers the home import freight rates (i.e., the foreign export freight rates).[26] Since such an indirect effect works by country pairs and is not absorbed by a set of our fixed effects, the estimates of tariff variables may end up capturing both the direct and indirect effects.

To minimize the indirect effects of tariffs, we restrict the sample to cover only products with little product differentiation as the third robustness check.[27] Since one source of the country pair-variant nature of export prices is imperfect competition in the goods markets, the indirect effects are likely to be weaker for the less-differentiated products. The IV results for the restricted sample, which are reported in columns (IV)-(VI) in Table 2, are similar to those when excluding landlocked countries. They show negative coefficients for importer's tariffs and positive coefficients for exporter's tariffs though the coefficient for importer's tariffs is insignificant in column (VI). Thus, even when focusing on the case where the indirect effects are expected to be weak, we still find the results to be consistent with our expectation.

Next, we examine two features of our tariff variables. First, they are weighted averages of the product-level tariffs, with import values as the weight, because not only import quantity but also import prices may determine freight rates. Nevertheless, we also check how the model performs if we use only import quantity (i.e., weight in ton) as the weight for averaging. The results are shown in columns (I)-(III) in Table 3. Second, our tariff variables cover the tariffs in all commodities subject to containerized trade because the freight rates on a particular good may depend not only on the trade volume or value of the good itself but on the total trade volume or value between the trading countries. Nevertheless, we also estimate the model with the tariff variables defined at a country pair-product-year level. The results are shown in columns (IV)-(VI). In both types of estimation, the coefficients for importer's tariffs and exporter's

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[26] We thank one of the reviewers for suggesting this mechanism. The negative relationship between home tariffs and home (fob) import prices is empirically confirmed by Hummels and Skiba (2004).

[27] Specifically, we compute the share of products categorized into either "goods traded on an organized exchange" or "reference priced" in the liberal classification in Rauch (1999), in terms of item numbers at an HS six-digit level. We compute such a share for each HS two-digit code and then restrict the sample to those HS two-digit codes with the shares above the median among all codes.

tariffs are negatively and positively estimated, respectively (except for the OLS results). However, some of these specifications yield insignificant estimates. This insignificant result may imply that we should consider average tariff rates across all goods shipped under containerized trade, instead of product-specific tariffs. It also supports the use of values rather than quantity alone as the weight for computing average tariffs.

=== Table 3 ===

Last, we also conduct two placebo tests. The first test applies the tariff rates in one year ahead instead of the contemporaneous tariff rates as a regressor. Such future tariff rates should not affect the freight rates in the current year. The results are shown in columns (I)-(III) of Table 4. The IV estimation does not show any significant results in the tariff variables.[28] As the second test, we regress the freight rates for tanker shipping on tanker tariffs by using container tariffs as instruments (columns IV and V). Since tankers always come back empty in the backhaul, tanker shipping faces backhaul problems. Thus, unlike container shipping, our theoretical prediction should not apply to tanker shipping.[29] We observe that the instruments are weak and that all tariff variables have insignificant coefficients. While the insignificant results for the exporter's tariffs are consistent with the presence of backhaul problems for tankers, those for the importer's tariffs indicate that freight rates in these oil-related products are not sensitive to their tariffs.[30]

=== Table 4 ===

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[28] Here we do not present results with both the contemporaneous and future tariff rates on the right-hand side because they are highly correlated. Indeed, the specification with both of these tariffs yields implausible results (Table B3 in Appendix B). For example, although both the coefficients for the contemporaneous and future exporter's tariff rates are significant, they have almost the same magnitude but with opposite sign.

[29] The sample for this placebo test is smaller because only two HS two-digit products are shipped by tankers, i.e., 15 (animal or vegetable fats and oils) and 27 (mineral fuels, mineral oils and products of their distillation).

[30] Some additional regressions are conducted as supplementary analyses. First, we examine the lagged effects of a tariff change on freight rates (Table B4 in Appendix B). Second, we examine the role of imbalance in the shipment volume of bilateral trade between trading partners (Table B5 in Appendix B). Third, we examine the role of port call in freight rates. Container ships may call at various ports on the way to import countries. In particular, the number of such ports and countries is likely to become larger when the distance between two countries is larger. Therefore, we introduce the interaction term of exporter's tariffs with the log of geographical distance between trading countries (Table B6 in Appendix B). However, we did not find significant results in all of these cases.

4.3. Effects on Trade Quantity

The results thus far support the theoretical predictions regarding the effects of tariff rates on freight rates. Here we examine the effects of tariff rates on trade volume by estimating the following gravity equation.

$$\ln Export_{ijpt} = \gamma_1 \ln(1 + Tariff_{ijt}) + \gamma_2 \ln(1 + Tariff_{jit}) + u_{ijp} + u_{ipt} + u_{jpt} + \epsilon_{ijt},$$

where $Export_{ijpt}$ represents the export (value or quantity measured in kilogram) of product p (defined at an HS two-digit level) from country i to country j in year t. As in the analysis of freight rates, we focus on trade in products subject to containerized trade. The independent variables are the same as in the previous specifications.

To our best knowledge, this is the first study that examines the role of exporter's tariffs in the gravity analysis. Furthermore, our importer's tariff variable is a little different from the one used in the literature (e.g., Disdier et al., 2015) because it covers tariffs on all goods that are subject to containerized trade. As demonstrated in Section 2, we expect both the coefficients to be negative. As in the analysis for freight rates, we employ the IV method by using the same instruments. Our dataset for this gravity estimation includes trade among 148 countries during 1995-2014.[31] The trade data are again obtained from the UN Comtrade.

We begin with the gravity estimation for export values as usual. The IV results are reported in columns (I) and (II) in Table 5 and show that our instruments work as well as in the analysis for freight rates. Consistent with our expectation, the coefficients for both importer's and exporter's tariffs are negative and significant. Thus, a country's reduction of import tariff rates against a trading partner's goods increases not only the imports from but also the exports to the partner. We obtain the same results when regressing the export quantity (measured in kilogram instead of the export value) as shown in columns (III) and (IV) of Table 5.

=== Table 5 ===

[31] It is common in the gravity literature to address an issue of zero-valued trade, i.e., sample-selection issue, by employing the Poisson pseudo-maximum likelihood estimation technique (Silva and Tenreyro, 2006) or the extended version of the Heckman two-step estimation (Helpman et al., 2008). However, we apply weighted average of tariff rates, which are another critical variable in our analysis, based on the tariff variables that are available only for country pairs with positive trade. Therefore, in this paper, we do not take this issue into account.

Our conjecture is that a change in a country's import tariffs affects its exports by inducing a change in the freight rates. However, there may exist other mechanisms that explain a similar relationship between the exporter's tariffs and exports.[32] One example is the trade facilitation effect: a dramatic increase in trade with a specific country may reduce broadly-defined trade costs with that country.[33] For example, suppose that the U.S. decreases tariffs against imports from China and thus increases imports from China. This increase may encourage the U.S. government to hire more trade officials who can speak Mandarin and write better-quality contacts with Chinese shipping and trading firms. As a result, the use of these improved facilities enables trading firms in the U.S. to export to China with lower costs. This mechanism may be present for a country with its relatively major exporters.

To minimize such effects in our estimation, we exclude the observations associated with such major exporters for each country. Specifically, we restrict the exporters for each country in the sample only to those whose shares in the country's total imports are less than the average share across all exporters. Trade with such countries is unlikely to induce importing countries to drastically improve their trade facilities. The results are reported in columns (V) and (VI) in Table 5. In particular, column (V) shows that both the importer's and exporter's tariffs have negative and significant coefficients. In column (VI), both tariff variables have negative coefficients, but the coefficient for the exporter's tariffs is insignificant. To summarize, these results imply that trade facilitation mechanism alone does not explain the export-enhancing effects of import-tariff reductions.

5. Conclusion

Our empirical investigation based on the freight rates and the bilateral trade data provides support for Ishikawa and Tarui's (2018) theoretical prediction that for containerized trade subject to backhaul problems, home tariff reductions induce the

[32] For example, as mentioned in Section 1, when a country reduces tariff rates on intermediate inputs, the country's export of finished products that use these inputs may increase because the decrease in the import prices of inputs lowers the export prices of finished goods. This channel is controlled for by our exporter-product-year fixed effects. In this context, however, our use of weight as a quantity measure (i.e., a dependent variable) may be somewhat problematic. In this paper, export quantity is measured by weight rather than the number of units simply because of the data limitation. However, an input tariff reduction may encourage firms to upgrade their products by reducing the weight (Bas and Strauss-Kahn, 2015). In this case, even if the number of unit increases, the weight may not change much. As a result, our use of weight may underestimate the effects of exporter's tariffs on exports.

[33] We thank one of the reviewers for suggesting this mechanism.

transport firms to lower their freight rates on home exports, thereby expanding not only home imports but also home exports. Our identification of the effects of tariffs on freight rates relies on the use of tariff rates for goods that are not traded by containers (i.e., dirty bulk and tankers) to instrument the tariffs on containerized trade. The robustness checks regarding the specifications of the freight rates, the weights used to compute the average tariff rates across traded goods as well as a few placebo tests support the main findings. As for the positive effect of a country's import liberalization on its exports, our study identifies an overlooked channel, i.e., endogenous transport costs. Given the global trend of trade liberalization, this finding implies that reducing import barriers may indeed enhance countries' exports instead of affecting them negatively.

The fact that tariff rates in one direction affect freight rates and trade in both directions has important implications on the welfare impacts of tariff reduction.[34] The trade elasticity (the elasticity of bilateral imports with respect to variable trade costs) plays a key role in estimating the welfare impacts (Costinot and Rodríguez-Clare, 2014). Such elasticity values may be obtained by gravity estimations—for example, by regressing (logged) trade values on the importer's tariffs.[35] However, when the importer's tariffs have significant effects on not only imports but also freight rates on imports, the estimated coefficient for the importer's tariffs includes not only the price elasticity of demand but also the tariff elasticity of freight rates. Furthermore, when exporting countries' import tariffs affect the freight rates on their exports, ignoring their tariffs in the gravity estimation yields omitted-variable bias in the estimates on the importer's tariffs (if these two tariffs are correlated through, for example, RTAs). In short, given the endogeneity of transport costs as we identify in this paper, the coefficient for importer's tariffs in the gravity estimation may no longer indicate the pure and consistent estimates on the price elasticity of demand.

[34] We thank Arnaud Costinot (a co-editor of this journal) for suggesting this implication.
[35] Head and Meyer (2014) provide a review of the gravity approach to estimate the trade elasticity.

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Table 1. Baseline Results

	(I)	(II)	(III)	(IV)	(V)	(VI)
Importer's tariff	-0.392*	-0.855**	-0.698*	-0.376*	-0.798**	-0.654*
	[0.231]	[0.422]	[0.409]	[0.210]	[0.392]	[0.380]
Exporter's tariff	0.118	1.142***	0.956**	0.117	1.052***	0.920**
	[0.190]	[0.442]	[0.408]	[0.167]	[0.398]	[0.368]
Method	OLS	IV1	IV2	OLS	IV1	IV2
Tariff	Log	Log	Log	Level	Level	Level
R-squared	0.8394			0.8394		
KP rk LM statistic		35.531	38.139		33.957	36.468
KP rk Wald F statistic		32.871	19.509		28.332	17.142
Hansen J statistic			4.366			3.032
(p-value)			0.1127			0.2196
Number of observations	74,791	74,791	74,791	74,791	74,791	74,791

Notes: The dependent variable is the log of freight rates per weight at a product level (HS two-digit). ***, **, and * represent significance at the 1%, 5%, and 10% statistical levels, respectively. In the parenthesis is the standard error clustered by country pair and product-year. In all specifications, we control for country pair-product fixed effects, export country-product-year fixed effects, and import country-product-year fixed effects. While we use exporter's and importer's dirty-bulk tariffs in "IV1" as instruments, their tanker tariffs in addition to them are used in "IV2." "KP rk LM statistic" and "KP rk Wald F statistic" indicate Kleibergen-Paap rk LM statistic and Kleibergen-Paap rk Wald F statistic, respectively. In "Log," importer's tariff indicates ln (1 + Importer's tariffs) while it is simply Importer's tariffs in "Level."

Table 2. Robustness Check: Subsamples

	(I)	(II)	(III)	(IV)	(V)	(VI)
ln (1 + Importer's tariff)	-0.392*	-0.814*	-0.647	-0.432	-0.976*	-0.816
	[0.235]	[0.423]	[0.412]	[0.286]	[0.574]	[0.544]
ln (1 + Exporter's tariff)	0.12	1.078**	0.886**	0.012	1.389**	1.111**
	[0.192]	[0.437]	[0.404]	[0.236]	[0.567]	[0.503]
Method	OLS	IV1	IV2	OLS	IV1	IV2
R-squared	0.8405			0.8219		
KP rk LM statistic		35.109	37.522		32.431	35.323
KP rk Wald F statistic		32.859	19.379		29.123	19.874
Hansen J statistic			4.729			3.765
(p-value)			0.094			0.1522
Number of observations	72,282	72,282	72,282	42,102	42,102	42,102

Notes: The dependent variable is the log of freight rates per weight at a product level (HS two-digit). ***, **, and * represent significance at the 1%, 5%, and 10% statistical levels, respectively. In the parenthesis is the standard error clustered by country pair and product-year. In all specifications, we control for country pair-product fixed effects, export country-product-year fixed effects, and import country-product-year fixed effects. While we use exporter’s and importer’s dirty-bulk tariffs in “IV1” as instruments, their tanker tariffs in addition to them are used in “IV2.” “KP rk LM statistic” and “KP rk Wald F statistic” indicate Kleibergen-Paap rk LM statistic and Kleibergen-Paap rk Wald F statistic, respectively. In columns (I)-(III), we exclude observations associated with landlocked countries. In columns (IV)-(VI), we exclude differentiated products.

Table 3. Quantity Weight and Product-level Tariffs

	(I)	(II)	(III)	(IV)	(V)	(VI)
ln (1 + Importer's tariff)	-0.364	-0.726	-0.448	0.680***	-0.658	-0.491
	[0.250]	[0.612]	[0.559]	[0.190]	[0.455]	[0.441]
ln (1 + Exporter's tariff)	0.112	1.182**	0.935**	-0.095	1.145**	0.984**
	[0.190]	[0.483]	[0.428]	[0.109]	[0.513]	[0.495]
Weight in tariff variables	Quantity	Quantity	Quantity	Value	Value	Value
Dimension in tariff variables	*ijt*	*ijt*	*ijt*	*ijpt*	*ijpt*	*ijpt*
Method	OLS	IV1	IV2	OLS	IV1	IV2
R-squared	0.8394			0.847		
KP rk LM statistic		31.636	34.216		34.787	37.152
KP rk Wald F statistic		26.363	16.71		17.975	11.388
Hansen J statistic			3.585			4.757
(p-value)			0.1666			0.0927
Number of observations	74,791	74,791	74,791	57,385	57,385	57,385

Notes: The dependent variable is the log of freight rates per weight at a product level (HS two-digit). ***, **, and * represent significance at the 1%, 5%, and 10% statistical levels, respectively. In the parenthesis is the standard error clustered by country pair and product-year. In all specifications, we control for country pair-product fixed effects, export country-product-year fixed effects, and import country-product-year fixed effects. While we use exporter's and importer's dirty-bulk tariffs in "IV1" as instruments, their tanker tariffs in addition to them are used in "IV2." "KP rk LM statistic" and "KP rk Wald F statistic" indicate Kleibergen-Paap rk LM statistic and Kleibergen-Paap rk Wald F statistic, respectively. In column "Quantity" in "Weight in tariff variables," tariff variables are constructed by using quantity as a weight in the aggregation. In column "*ijpt*" in "Dimension in tariff variables," we use tariff variables defined at a country pair-product-year level.

Table 4. Placebo Tests

	(I)	(II)	(III)	(IV)	(V)
ln (1 + Importer's tariff (*t* +1))	-0.399*	-0.286	-0.039		
	[0.239]	[0.479]	[0.453]		
ln (1 + Importer's tariff (*t*))				1.529	2.455
				[1.403]	[5.844]
ln (1 + Exporter's tariff (*t* +1))	-0.162	-0.289	-0.638		
	[0.189]	[0.600]	[0.516]		
ln (1 + Exporter's tariff (*t*))				0.315	-4.873
				[0.403]	[2.849]
Method	OLS	IV1	IV2	OLS	IV
Commodity	Container	Container	Container	Tanker	Tanker
R-squared	0.8465			0.7852	
KP rk LM statistic		19.075	28.944		4.886
KP rk Wald F statistic		9.859	10.596		3.466
Hansen J statistic			3.345		
(p-value)			0.1878		
Number of observations	67,725	67,725	67,725	2,952	2,952

Notes: The dependent variable is the log of freight rates per weight at a product level (HS two-digit). ***, **, and * represent significance at the 1%, 5%, and 10% statistical levels, respectively. In the parenthesis is the standard error clustered by country pair and product-year. In all specifications, we control for country pair-product fixed effects, export country-product-year fixed effects, and import country-product-year fixed effects. In "Container" ("Tanker") in "Commodity," we consider freight rates and tariff rates in container (tanker) trade. While we use exporter's and importer's dirty-bulk tariffs in "IV1" as instruments, their tanker tariffs in addition to them are used in "IV2." In "IV" in the commodity of "Tanker," we use exporter's and importer's container tariffs as instruments. "KP rk LM statistic" and "KP rk Wald F statistic" indicate Kleibergen-Paap rk LM statistic and Kleibergen-Paap rk Wald F statistic, respectively.

Table 5. Gravity Estimation

	(I)	(II)	(III)	(IV)	(V)	(VI)
ln (1 + Importer's tariff)	-0.726**	-0.631**	-0.834**	-0.661*	-1.382***	-1.192***
	[0.338]	[0.304]	[0.403]	[0.359]	[0.527]	[0.443]
ln (1 + Exporter's tariff)	-0.768**	-0.544*	-0.956**	-0.633*	-1.027**	-0.626
	[0.354]	[0.329]	[0.406]	[0.367]	[0.511]	[0.438]
Method	IV1	IV2	IV1	IV2	IV1	IV2
Dependent variable	Value	Value	Quantity	Quantity	Quantity	Quantity
KP rk LM statistic	209.177	238.771	209.177	238.771	167.499	207.373
KP rk Wald F statistic	31.829	45.35	31.829	45.35	26.138	39.146
Hansen J statistic		2.447		4.209		4.699
(p-value)		0.2942		0.1219		0.0954
Number of observations	3,915,211	3,915,211	3,915,211	3,915,211	2,851,645	2,851,645

Notes: The dependent variable is the log of export values or export quantity at a product level (HS two-digit). ***, **, and * represent significance at the 1%, 5%, and 10% statistical levels, respectively. In the parenthesis is the standard error clustered by country pair and product-year. In all specifications, we control for country pair-product fixed effects, export country-product-year fixed effects, and import country-product-year fixed effects. While we use exporter's and importer's dirty-bulk tariffs in "IV1" as instruments, their tanker tariffs in addition to them are used in "IV2." "KP rk LM statistic" and "KP rk Wald F statistic" indicate Kleibergen-Paap rk LM statistic and Kleibergen-Paap rk Wald F statistic, respectively. To control for the trade facilitation effect, in columns (V) and (VI), we exclude the observations associated with major exporters for each country: specifically, we restrict the exporters for each in the sample only to those whose shares in the country's total imports are less than the average share across all exporters.

Appendix A. Derivation of Equation (1)

In this appendix, we derive equation (1). The first order conditions for shipping between country i and j are given by

$$\phi^{ij} + (T_{ij} - r + \lambda)\phi_T^{ij} = 0, \qquad \phi^{ji} + (T_{ij} - \lambda)\phi_T^{ji} = 0, \qquad \phi^{ij} - \phi^{ji} = 0,$$

where λ represents the Lagrangian multiplier associated with the constraint and $\phi_T^{ij} \equiv \partial\phi^{ij}/\partial T_{ij}$. Total differentiation of the first order condition yields

$$\phi_T^{ij} dT_{ij} + \phi_\tau^{ij} d\tau_j + (T_{ij} - r + \lambda)(\phi_{TT}^{ij} dT_{ij} + \phi_{T\tau}^{ij} d\tau_j) + \phi_T^{ij}(dT_{ij} + d\lambda) = 0,$$

$$\phi_T^{ji} dT_{ji} + (T_{ji} - \lambda)\phi_{TT}^{ji} dT_{ji} + \phi_T^{ji}(dT_{ji} - d\lambda) = 0,$$

$$\phi_T^{ij} dT_{ij} + \phi_{\tau_j}^{ij} d\tau_j - \phi_T^{ji} dT_{ji} = 0.$$

It follows that

$$\begin{pmatrix} 2\phi_T^{ij} + (T_{ij} - r + \lambda)\phi_{TT}^{ij} & 0 & \phi_T^{ij} \\ 0 & 2\phi_T^{ji} + (T_{ji} - \lambda)\phi_{TT}^{ji} & -\phi_T^{ji} \\ \phi_T^{ij} & -\phi_T^{ji} & 0 \end{pmatrix} \begin{pmatrix} dT_{ij} \\ dT_{ji} \\ d\lambda \end{pmatrix}$$

$$= \begin{pmatrix} -\{\phi_\tau^{ij} + (T_{ij} - r + \lambda)\phi_{T\tau}^{ij}\} \\ 0 \\ -\phi_\tau^{ij} \end{pmatrix} d\tau_j.$$

Let F represent the 3x3 matrix on the left-hand side. Evaluated at the solution, the determinant satisfies

$$|F| = -\phi_T^{ij}(2 - \varepsilon^{ij})(\phi_T^{ji})^2 - \phi_T^{ji}(2 - \varepsilon^{ji})(\phi_T^{ij})^2,$$

where $\varepsilon^{ij} \equiv \phi^{ij}\phi_{TT}^{ij}/(\phi_T^{ij})^2$ represents the elasticity of the slope of the inverse demand curve for shipping from i to j.

By following the literature (Brander and Spencer 1984; Ishikawa and Spencer 1999), we assume the demand functions are not too convex: $2 - \varepsilon^{ij} > 0$ and $2 - \varepsilon^{ji} > 0$, so that $|F| > 0$, i.e., the second order condition for the transport firm's profit maximization holds. Apply Cramer's rule to obtain

$$\frac{\partial T_{ij}}{\partial \tau_j} = \frac{1}{|F|} \begin{vmatrix} -\{\phi_\tau^{ij} + (T_{ij} - r + \lambda)\phi_{T\tau}^{ij}\} & 0 & \phi_T^{ij} \\ 0 & 2\phi_T^{ji} + (T_{ji} - \lambda)\phi_{TT}^{ji} & -\phi_T^{ji} \\ -\phi_\tau^{ij} & -\phi_T^{ji} & 0 \end{vmatrix}$$

$$= \left(\frac{1}{|F|}\right)\left[\{\phi_\tau^{ij} + (T_{ij} - r + \lambda)\phi_{T\tau}^{ij}\}(\phi_T^{ji})^2 + \{2\phi_T^{ji} + (T_{ji} - \lambda)\phi_{TT}^{ji}\}\phi_T^{ij}\phi_\tau^{ij}\right].$$

To evaluate the expression inside the square brackets, we can compute the derivatives of function ϕ^{ij} by totally differentiating the equilibrium condition on shipping, $(1+\tau_j)S_i(X_{ij}) + T_{AB} = D_j(X_{ij})$:

$$(1+\tau_j)S_i' dX_{ij} + dT_{ij} + S_i d\tau_j = D_j' dX_{ij}.$$

It follows that

$$\frac{\partial \phi^{ij}}{\partial T_{ij}} \equiv \phi_T^{ij} = \frac{-1}{(1+\tau_j)S_i' - D_j'} = -1/Z < 0,$$

$$\frac{\partial \phi^{ij}}{\partial \tau_j} \equiv \phi_\tau^{ij} = \frac{-S_i}{(1+\tau_j)S_i' - D_j'} = S_i \phi_T^{ij} < 0,$$

$$\frac{\partial^2 \phi^{ij}}{\partial T_{ij}^2} \equiv \phi_{TT}^{ij} = Z^{-2}\{(1+\tau_j)S_i'' - D_j''\}\phi_T^{ij},$$

$$\frac{\partial^2 \phi^{ij}}{\partial \tau_j \partial T_{ij}} \equiv \phi_{T\tau}^{ij} = Z^{-2}\{(1+\tau_j)S_i'' - D_j''\}\phi_\tau^{ij} + Z^{-2}S_i',$$

where $Z \equiv (1+\tau_j)S_i' - D_j' > 0$. Substituting these terms into the expression of $\partial T_{ij}/\partial \tau_j$, we have

$$\frac{\partial T_{ij}}{\partial \tau_j} = \left(\frac{1}{|F|}\right)\left[\left\{S_i\phi_T^{ij} - \frac{\phi^{ij}}{\phi_T^{ij}}\left(S_i\phi_{TT}^{ij} + Z^{-2}S_i'\right)\right\}\left(\phi_T^{ji}\right)^2 + \left\{2\phi_T^{ji} - \frac{\phi^{ji}}{\phi_T^{ji}}\phi_{TT}^{ji}\right\}S_i\left(\phi_T^{ij}\right)^2\right]$$

$$= \frac{1}{|F|}\left[S_i\phi_T^{ij}\left\{1 - \varepsilon^{ij} - \frac{1}{\varepsilon_S^i}\right\}\left(\phi_T^{ji}\right)^2 + \phi_T^{ji}\{2 - \varepsilon^{ji}\}S_i\left(\phi_T^{ij}\right)^2\right],$$

where $\varepsilon_S^i \equiv S_i/(\phi^{ij}S_i')$ is the price elasticity of excess supply from country i.

Assumption 1: $1 - \varepsilon^{ij} - \frac{1}{\varepsilon_S^i} > 0$.

Under Assumption 1, we have $\partial T_{ij}/\partial \tau_j < 0$: the equilibrium freight rate from country i to country j is decreasing in the tariff by country j. Assumption 1 holds if the inverse demand for shipping is not too convex and if the price elasticity of excess supply from each country is not too low.

Turning to $\partial T_{ji}/\partial \tau_j$, we have

$$\frac{\partial T_{ji}}{\partial \tau_j} = \frac{1}{|F|}\begin{vmatrix} 2\phi_T^{ij} + (T_{ij} - r + \lambda)\phi_{TT}^{ij} & -\{\phi_\tau^{ij} + (T_{ij} - r + \lambda)\phi_{T\tau}^{ij}\} & \phi_T^{ij} \\ 0 & 0 & -\phi_T^{ji} \\ \phi_T^{ij} & -\phi_\tau^{ij} & 0 \end{vmatrix}$$

$$= \left(\frac{1}{|F|}\right)\left[\{\phi_\tau^{ij} + (T_{ij} - r + \lambda)\phi_{T\tau}^{ij}\}\phi_T^{ij}\phi_T^{ji} - \{2\phi_T^{ij} + (T_{ij} - r + \lambda)\phi_{TT}^{ij}\}\phi_T^{ji}\phi_\tau^{ij}\right],$$

where the expression inside the square brackets reduces to

$$-\phi_\tau^{ij}\phi_T^{ij}\phi_T^{ji} + \phi_T^{ji}(T_{ij} - r + \lambda)\left(\phi_T^{ij}\phi_{T\tau}^{ij} - \phi_\tau^{ij}\phi_{TT}^{ij}\right). \qquad (A1)$$

The first term is positive. Rearrange the second term to obtain

$$\phi_T^{ji}\left(T_{ij} - r + \lambda\right)\left(\phi_T^{ij}\phi_{T\tau}^{ij} - \phi_\tau^{ij}\phi_{TT}^{ij}\right) = \phi_T^{ji}\left(T_{ij} - r + \lambda\right)Z^{-2}S_i'\phi_T^{ij} > 0.$$

We conclude that $\frac{\partial T_{ji}^*}{\partial \tau_j} > 0$ and $\frac{\partial T_{ij}^*}{\partial \tau_j} < 0$.

We can apply further substitutions to express $\partial T_{ji}/\partial \tau_j$ in terms of various intuitive elasticity measures. The expression (A1) is equal to

$$-\frac{\phi_T^{ji}}{Z^2}\left(S_i + \phi^{ij}S_i'\right) = -p_i\left(1 + \frac{1}{\varepsilon_S^i}\right)\frac{\phi_T^{ji}}{Z^2},$$

where $\varepsilon_S^i \equiv S_i/\left(\phi^{ij}S_i'\right)$ is the price elasticity of excess supply from country i. Therefore,

$$\frac{\partial T_{ji}}{\partial \tau_j}\frac{\tau_j}{T_{ji}} = \frac{\tau_j}{T_{ji}/p_i} \cdot \frac{\left(1 + \frac{1}{\varepsilon_S^i}\right)\eta^{ij}\frac{\phi^{ij}}{T_{ij}}}{\eta^{ij}\left(2 - \varepsilon^{ji}\right)\frac{\phi^{ij}}{T_{ij}} + \eta^{ji}\left(2 - \varepsilon^{ij}\right)\frac{\phi^{ji}}{T_{ji}}},$$

where $\eta^{ij} \equiv \frac{\partial X_{ij}}{\partial T_{ij}}\frac{T_{ij}}{X_{ij}}$ is the elasticity of shipping with respect to the freight rate.

■

Appendix B. Other Tables

Table B1. Descriptive Statistics

	Obs	Mean	Std. Dev.	Min	Max
ln Freight	74,791	-1.465	0.908	-9.210	2.856
ln (1 + Importer's container tariff)	74,791	0.066	0.049	0	0.206
ln (1 + Exporter's container tariff)	74,791	0.060	0.054	0	0.373
ln (1 + Importer's dirty-bulk tariff)	74,791	0.034	0.035	0	0.153
ln (1 + Exporter's dirty-bulk tariff)	74,791	0.030	0.042	0	0.364
ln (1 + Importer's tanker tariff)	74,791	0.031	0.042	0	0.274
ln (1 + Exporter's tanker tariff)	74,791	0.049	0.079	0	0.796
ln Value	3,915,211	6.357	2.966	0	18.700
ln Quantity	3,915,211	4.496	3.516	-14.709	20.422

Source: The authors' computation.

Table B2. First-stage Results in Table 1

	(II)		(III)		(V)		(VI)	
	Importer	Exporter	Importer	Exporter	Importer	Exporter	Importer	Exporter
Importer's tariff (Dirty-bulk)	0.722***	0.263***	0.689***	0.250***	0.731***	0.279***	0.699***	0.269***
	[0.071]	[0.053]	[0.069]	[0.053]	[0.074]	[0.056]	[0.073]	[0.057]
Exporter's tariff (Dirty-bulk)	-0.028	0.451***	-0.044	0.446***	-0.032	0.427***	-0.046	0.425***
	[0.044]	[0.069]	[0.042]	[0.065]	[0.042]	[0.069]	[0.041]	[0.067]
Importer's tariff (Tanker)			0.101***	0.001			0.104***	0.001
			[0.027]	[0.032]			[0.027]	[0.034]
Exporter's tariff (Tanker)			0.017	0.063***			0.009	0.046***
			[0.019]	[0.016]			[0.016]	[0.013]

Notes: The dependent variable is importer's or exporter's container tariffs. All tariff variables are taken their logs. ***, **, and * represent significance at the 1%, 5%, and 10% statistical levels, respectively. In the parenthesis is the standard error clustered by country pair and product-year. Column numbers correspond to those in Table 1.

Table B3. Lead Effects

	(I)	(II)	(III)
ln (1 + Importer's tariff (t+1))	-0.509*	0.686	0.881
	[0.270]	[0.833]	[0.690]
ln (1 + Importer's tariff (t))	0.163	-1.164	-1.191*
	[0.287]	[0.766]	[0.686]
ln (1 + Exporter's tariff (t+1))	-0.255	-2.531**	-2.787***
	[0.192]	[1.037]	[0.854]
ln (1 + Exporter's tariff (t))	0.209	2.601***	2.678***
	[0.209]	[0.835]	[0.809]
Method	OLS	IV1	IV2
Commodity	Container	Container	Container
R-squared	0.8465		
KP rk LM statistic		10.558	20.831
KP rk Wald F statistic		2.461	2.763
Hansen J statistic			1.719
(p-value)			0.7872
Number of observations	67,725	67,725	67,725

Notes: The dependent variable is the log of freight rates per weight at a product level (HS two-digit). ***, **, and * represent significance at the 1%, 5%, and 10% statistical levels, respectively. In the parenthesis is the standard error clustered by country pair and product-year. In all specifications, we control for country pair-product fixed effects, export country-product-year fixed effects, and import country-product-year fixed effects. While we use exporter's and importer's dirty-bulk tariffs in "IV1" as instruments, their tanker tariffs in addition to them are used in "IV2." "KP rk LM statistic" and "KP rk Wald F statistic" indicate Kleibergen-Paap rk LM statistic and Kleibergen-Paap rk Wald F statistic, respectively.

Table B4. Lagged Effects

	(I)	(II)	(III)
ln (1 + Importer's tariff (t))	-0.411	-1.456**	-1.071
	[0.260]	[0.707]	[0.655]
ln (1 + Importer's tariff ($t-1$))	0.007	0.422	0.196
	[0.211]	[0.679]	[0.628]
ln (1 + Exporter's tariff (t))	-0.025	1.702**	1.279*
	[0.218]	[0.807]	[0.750]
ln (1 + Exporter's tariff ($t-1$))	0.293**	-0.148	-0.043
	[0.137]	[0.760]	[0.658]
Method	OLS	IV1	IV2
R-squared	0.8496		
KP rk LM statistic		13.942	20.555
KP rk Wald F statistic		3.45	3.446
Hansen J statistic			5.967
(p-value)			0.2017
Number of observations	62,800	62,800	62,800

Notes: The dependent variable is the log of freight rates per weight at a product level (HS two-digit). ***, **, and * represent significance at the 1%, 5%, and 10% statistical levels, respectively. In the parenthesis is the standard error clustered by country pair and product-year. In all specifications, we control for country pair-product fixed effects, export country-product-year fixed effects, and import country-product-year fixed effects. While we use exporter's and importer's dirty-bulk tariffs in "IV1" as instruments, their tanker tariffs in addition to them are used in "IV2." "KP rk LM statistic" and "KP rk Wald F statistic" indicate Kleibergen-Paap rk LM statistic and Kleibergen-Paap rk Wald F statistic, respectively.

Table B5. Exporter’s Tariff Effects According to Shipment Gap

	(I)	(II)	(III)
ln (1 + Importer's tariff)	-0.402*	-0.880**	-0.709*
	[0.226]	[0.420]	[0.405]
ln (1 + Exporter's tariff) * Q1.Gap	0.331	1.105	1.094*
	[0.394]	[0.696]	[0.647]
ln (1 + Exporter's tariff) * Q2.Gap	0.31	0.968	0.759
	[0.363]	[0.616]	[0.537]
ln (1 + Exporter's tariff) * Q3.Gap	0.373	1.287***	1.097**
	[0.239]	[0.445]	[0.428]
ln (1 + Exporter's tariff) * Q4.Gap	-0.324	0.971	0.81
	[0.295]	[0.663]	[0.584]
Method	OLS	IV1	IV2
R-squared	0.8395		
KP rk LM statistic		35.85	37.693
KP rk Wald F statistic		13.513	8.81
Hansen J statistic			5.864
(p-value)			0.3197
Number of observations	74,791	74,791	74,791

Notes: The dependent variable is the log of freight rates per weight at a product level (HS two-digit). ***, **, and * represent significance at the 1%, 5%, and 10% statistical levels, respectively. In the parenthesis is the standard error clustered by country pair and product-year. In all specifications, we control for country pair-product fixed effects, export country-product-year fixed effects, and import country-product-year fixed effects. While we use exporter’s and importer’s dirty-bulk tariffs in “IV1” as instruments, their tanker tariffs in addition to them are used in “IV2.” “KP rk LM statistic” and “KP rk Wald F statistic” indicate Kleibergen-Paap rk LM statistic and Kleibergen-Paap rk Wald F statistic, respectively. “Q*i*” is the *i*-th quantile dummy variable on Gap, which is an absolute difference in total trade volume between two countries.

Table B6. Exporter's Tariff Effects According to Distance

	(I)	(II)	(III)
ln (1 + Importer's tariff)	-0.367	-0.899**	-0.698*
	[0.238]	[0.427]	[0.410]
ln (1 + Exporter's tariff)	-1.125	-2.19	-0.915
	[1.751]	[2.996]	[2.678]
ln (1 + Exporter's tariff) * ln Distance	0.145	0.427	0.227
	[0.194]	[0.375]	[0.328]
Method	OLS	IV1	IV2
R-squared	0.8394		
KP rk LM statistic		22.412	32.24
KP rk Wald F statistic		8.469	8.776
Hansen J statistic			5.128
(p-value)			0.1626
Number of observations	74,791	74,791	74,791

Notes: The dependent variable is the log of freight rates per weight at a product level (HS two-digit). ***, **, and * represent significance at the 1%, 5%, and 10% statistical levels, respectively. In the parenthesis is the standard error clustered by country pair and product-year. In all specifications, we control for country pair-product fixed effects, export country-product-year fixed effects, and import country-product-year fixed effects. While we use exporter's and importer's dirty-bulk tariffs in "IV1" as instruments, their tanker tariffs in addition to them are used in "IV2." "KP rk LM statistic" and "KP rk Wald F statistic" indicate Kleibergen-Paap rk LM statistic and Kleibergen-Paap rk Wald F statistic, respectively. "ln Distance" is the log of geographical distance between trading countries.