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The Organization of International Trade

Abstract

This paper discusses how international trade is organized from export to trans-boundary transport to import. All evidence suggests that the transport sector is independent, may exercise market power and features strong economies of scale. We develop a model of a transport industry that operates under imperfect competition and economies of scale and two generic trade models in which export and import activities are either organized at arm's length or in a vertical partnership. Using a large dataset of maritime transport costs, tariffs and export prices, we test the model predictions and find that economies of scale beat market power: a decline in the tariff implies a decline in freight rates. Furthermore, our results are consistent only with international trade being organized in vertical partnerships because a tariff increase does not lead to a decrease in export prices.

JEL-Codes: F120, F140, R400.

Keywords: trade costs, transport costs, export prices, vertical integration.

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1 Introduction

How is international trade organized from export to transboundary transport to import? In standard models of international trade, an exporter is selling to a large number of foreign buyers, and in order to do so, may face institutional barriers to trade like tariffs and has to carry resource costs like transport costs. Usual assumptions in this context are that the pricing policy of the firm is confined to linear pricing, and that not only institutional barriers to trade but also transport costs are exogenous and fixed.[1] Our paper departs from these assumptions in order to explore how international trade is organized. First, we determine freight rates endogenously. For this purpose, we consider the role of transport carriers explicitly, and we find that they are predominantly independent agents that are likely to operate under significant increasing returns to scale. While this gives this industry market power, it may also imply that a larger trade volume will lead to lower freight rates due to declining unit transport costs. Second, we consider a model of vertical partnership as an alternative to the standard model of trade.[2]

After having developed the theoretical framework for transport markets and pricing behavior, we employ a large dataset of maritime transport costs, tariffs and export prices to investigate the role of transport costs empirically and to test which generic trade model is consistent with our empirical results. We first find that a decrease in tariffs leads to a reduction in freight rates, meaning that the economies of scale effect is dominant and strong on average. Trade liberalization is thus supported by decreasing freight rates: economies of scale beat market power. This is an important finding, in particular as transport costs have become relatively more important as a barrier to trade compared to tariffs in some regions.[3] Second, we find that the effect of tariffs on export prices is not negative as standard models would predict. These results are consistent only with the

[1] This standard model has been used to discuss and estimate the gains from trade, and it has been used to explore how market power and firm heterogeneity affect market performance and welfare. For a summary of models of perfect competition, see Feenstra (2015), Chapters 1 and 2, and for the seminal papers on trade and firm heterogeneity, see Eaton and Kortum (2002) and Melitz (2003). Arkolakis *et al.* (2012) show that the welfare gains from trade depend only on the expenditure share of domestic goods and the elasticity of imports with respect to trade costs in most standard models.

[2] In particular, the seminal work by Antràs (2003) and Antràs and Helpman (2004) has demonstrated the role of vertical partnerships in this context. See also Antràs (2016), Antràs and Chor (2013), Feenstra and Hanson (2005), and Grossman and Helpman (2002).

[3] See, for example, Moreira *et al.* (2008), who investigate Latin American and Caribbean trade.

vertical partnership model that allows trading partners to use nonlinear pricing schemes.

The theoretical literature on transport markets in international trade is not too large. Falvey (1976) was the first to consider the impact of tariffs on transport markets. He integrates a transport industry into a Heckscher-Ohlin framework, and he shows that a tariff, imposed on the labor-intensive import good, makes the relative input price for a capital-intensive transport industry decline and thus partially offsets the effect on the domestic relative price. Francois and Wooton (2001) model shipping firms in a Cournot oligopoly that compete in quantities, and they evaluate the effects of more competition. More recently, Ishikawa and Tarui (2018) use an oligopoly Cournot model in which carriers face the backhaul problem due to unbalanced trade, and they show that trade policy may also affect capacities for own exports. In a similar spirit, Behrens and Picard (2011) show that agglomeration increases outward freight rates and consequently freight rate differences imply a more even distribution of production. Brancaccio *et al.* (2017) employ a model of random matching to investigate the search frictions that may arise between exporters and available shipping capacities. The paper closest to ours is Hummels *et al.* (2009) that considers shipping scale economies as a regional public good and employs a technology choice model. They show that a tariff reduction leads to a freight rate increase for a given transport technology, but a technology change may reverse this effect as it may become profitable to employ a technology that has a large fixed cost with an increase in transport volume.[4] We will let the data tell us whether market power or economies of scale dominate the response to trade liberalization.

Note that dealing with maritime transport has several advantages. First, we stack the decks against vertical partnerships as distances are long on average.[5] Second, the interaction between economic activity and infrastructure in maritime transport is confined to vessel speed and capacity, and to port and channel infrastructure.[6] Land and rail transport is more complex and leads to backward and forward linkages with a lot of economic

[4]Kleinert and Spies (2011), using a monopolistic competition model for producers and also a technology choice model, show that freight rates do not only depend on distance, but also on the level of exports. Thus, they also support the existence of economies of scale in this industry.

[5]Rauch (1999) classifies products whether they are traded on an organized exchange and/or have a reference price or neither, and he finds finds that proximity is more important for differentiated products that are not traded on an organized exchange.

[6]See Clark *et al.* (2004) for the role of port efficiency.

activities both within countries and across borders. While connectivity and port services quality matter, countries have access to only a small number of ports handling overseas exports.[7] Third, price discrimination is much easier for carriers in maritime transport as strict documentation rules imply that a resale of transport services is nearly impossible and the carrier will know exactly the details of each shipment. Fourth, we find that carriers in maritime shipping are predominantly not vertically integrated, and this observation allows us to consider the carrier as an independent agent. And finally, the capacity of modern vessels (both bulk and container vessels) is so large that carriers might operate under substantial economies of scale, turning them into natural monopolists on some routes.[8]

In a second step, we go beyond the transport market. The analysis of export pricing behavior requires to distinguish between exporting at arm's length and exporting through cross-border vertical partnerships. Serving markets at arm's length is quick and easy, but does not allow specialized and tailor-made offers, is likely to be subject to arbitrage and is hence confined to linear pricing strategies. Vertical partnerships allow for these options, but at the same time, these partnerships are subject to constraints due to moral hazard and hold-up problems that will restrain the degree of cooperation in a partnership. Since all organizational forms have pros and cons, we may expect that the organizational design of international trade relations will be determined endogenously. It is thus important to know which design is most consistent with empirical evidence.

Our paper also makes a contribution to the emerging literature on the role of networks in international trade (see for example Bernard *et al.*, 2017, Eaton *et al.*, 2016, Lim, 2017). These papers show, among other things, how important backward and forward linkages are for the performance of an exporting firm. Furthermore, our paper also contributes to the literature that links goods and services trade, see for example Ariu *et al.* (2016,

[7]Márques-Ramos *et al.* (2011) show how connectivity and service quality matters for exports through Spanish ports, Limão and Venables (2001) discuss the importance of domestic transportation infrastructure for trade, Blonigen and Wilson (2008) show how port infrastructure affects trade flows, and Storeygard (2016) investigates the role of inter-city transport costs for sub-Saharan African cities. For a summary of the literature on the interaction between transport and economic activities, see Redding and Turner (2015), and for a model endogenizing transport costs and economic agglomeration, see Behrens *et al.* (2009).

[8]See UNCTAD (2016). In 2016, Maersk was the largest liner shipping company with a market share of 15.1%. The four largest liner shipping companies have a market share of 45.5% and all have no cross-ownership with large exporting or importing firms.

2017), Breinlich *et al.* (2016) and Crozet and Milet (2017). First, transport is a genuine complementary service that is required by any goods trade.[9] Second, it is well known that intra-firm trade within the boundaries of a multinational firm is complemented by the provision of headquarter and/or affiliate services; see for example Nordås (2010) for the role of intermediate services. Bundling goods and services trade allows partners in a vertical relationship to use nonlinear pricing schemes, and since our analysis supports that trade is organized in vertical partnerships, it also provides indirect evidence for the importance of complementary services trade.

The remainder of this paper is organized as follows. Section 2 reviews the literature on trade costs, the maritime transport industry and international pricing incentives to set the stage for our theoretical model and our empirical investigation. Section 3 discusses the implications of tariffs on freight rates, and it explores the behavior of export prices in two alternative setups, the standard trade model, and the vertical partnership model. Section 4 explains the databases we use and presents our empirical results. Section 5 offers some concluding remarks.

2 Transport Costs and Pricing Incentives

This section will provide a thorough overview of the role of trade and transport costs, the transport sector and export pricing behavior. It is one main insight of models using the gravity equation to estimate trade flows that trade costs play an important role, see for example Anderson and van Wincoop (2004). Furthermore, there is a large literature on trade elasticities that can explain gains from trade liberalization in standard models of trade, but the estimates differ substantially, see for example Arkolakis *et al.* (2012), Baier and Bergstrand (2001), Broda and Weinstein (2006), Caliendo and Parro (2015), Hillberry and Hummels (2013) and Romalis (2007). In this paper, we want to take a closer look at trade costs, and for this reason, it is important to distinguish between administrative

[9]According to Eurostat, transport services account for 17% of total services exports to countries outside the EU and for 19% of total services imports from countries outside of the EU in 2015, and this makes transport services exports and imports the second largest service category, outnumbered only by other business services. Eurostat distinguishes twelve service categories, see http://ec.europa.eu/eurostat/statistics-explained/index.php/EU_international_trade_in_transport_services, accessed February 1, 2018.

costs like tariffs and transport costs that arise due to the necessity to move goods across borders. This distinction is also empirically important. For example, using a constant elasticity of transformation function in a gravity equation, Baier and Bergstrand (2001) find that the relative contribution to trade growth from tariff reductions is about 25 %, but only about 8 % originates from transport cost reductions (and income growth adds about 67 %).[10]

While international trade can be organized by different transport modes (air, rail, truck, ship), maritime transport is the dominant form of long-distance shipping. Figure 1 exemplarily shows the modal shares for the imports by trade value of the EU27 from 2000 to 2016. In recent years sea transport accounted for about 50% of value imports followed by air transport (slightly more than 20%), road transport (around 15%) and "other"(around 10%). Modal shares for maritime transport are slightly lower, and shares for air and road transport are slightly higher for value exports of the EU27. When trade is measured in weight rather than values, maritime transport dominates even more with modal shares of around 80% for both importing and exporting.[11]

Maritime transport has several sub-modes, and the most important ones are bulk carriers and liners.[12] Bulk carriers usually go with a full load, but may face a backhaul problem as they usually go back empty. Liners publish freight tariffs and routes and run at scheduled times, and all liner trade is by container among developed countries (Helmick, 2002).[13] While bulk carriers run the risk of staying idle when not needed, liners may have to go with underutilized capacity, giving rise to potential economies of scale.[14] Interestingly, the degree of vertical integration is surprisingly low.[15] Casson (1986) con-

[10] Trade facilitation, that is, reducing trade costs, is also an important issue for the WTO. On February 22, 2017, the Trade Facilitation Agreement (TFA) among WTO members came into force that deals with the movement, release, and clearance of goods, and it offers measures to increase cooperation among customs authorities and provides technical assistance.

[11] Evidence in the literature suggests that Europe is the continent with the lowest modal share of maritime transportion. See Cristea *et al.* (2013) for a detailed provision of data on trade shares by transport mode for different regions in 2004.

[12] Bulk cargo does not have to be packed, but is poured into the vessel while general cargo needs packaging.

[13] For the impact of containerization on international trade, see Bernhofen *et al.* (2016).

[14] For example, Piorrong (1992) finds falling average costs over a substantial rate of output.

[15] This is even true for bulk carriers; for example, product oil and crude oil tankers are mostly not owned by oil companies. The Teekay Group is considered to be the largest tanker shipping company in the world.

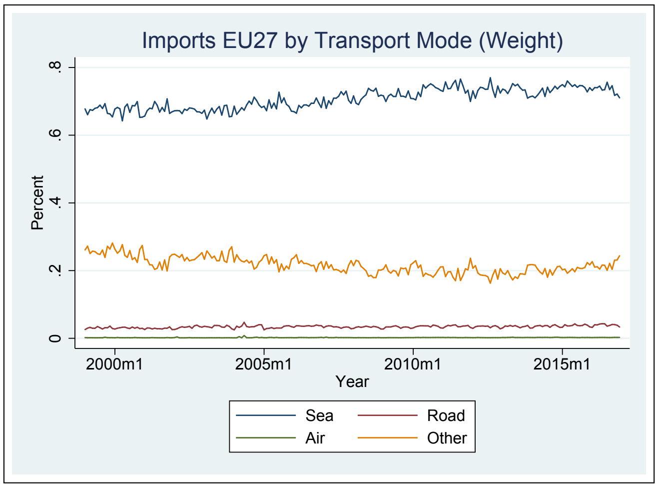

Figure 1
Source: EUROSTAT – http://epp.eurostat.ec.europa.eu/newxtweb/mainxtnet.do.

cludes that vertical integration is rare due to scale economies, and recent contributions on the corporate governance and capital structure of maritime shipping companies show that both ownership concentration, measured by the proportion of equity held by the largest shareholder, and the share held by institutional investors is relatively low.[16]

Transport costs could be considered as a fixed resource cost only if the market structure of this industry were competitive, and most of the literature, as explained above, does not consider the cost and market structures of the transport industry explicitly. However, there is strong evidence that carriers in the maritime transport industry have market power (Hummels *et al.* 2009). In the past, this industry was even allowed to fix freight rates in so-called conferences. Both the US and Europe have liberalized the maritime shipping market,[17] but this development does not mean that this market has become very

The top six companies carrying crude oil are all independent from oil companies (see Investopedia, 2015).

[16]See Tsionas *et al.* (2012) who report an ownership concentration below 34% on average, and Andreou *et al.* (2015) who report that about 20% are held only by institutional investors in their respective datasets. Giannakopoulou *et al.* (2016) report that a large share of the maritime shipping firms in Greece are still run as a family business. Any vertical integration in the maritime industry is obviously confined to port management and land logistics (see Altuntaş and Göçer, 2014), but does not extend to freight generation.

[17]The US Shipping Act of 1984 opened conferences to outsiders, eliminated loyalty contracts and allowed conference members to deviate from conference rates with 10 days notice. Fox (1995), however, concludes that this had no impact on market performance. McCutcheon (1997) argues that antitrust made

competitive. Conferences were replaced by alliances that aim at cross route rationalization and exploiting economies of density, and there is evidence that exporters have not too many carrier options to choose from. For example, from 2004 to 2016 UNCTAD (2016) reports a substantial decline of 35% in the number of carriers competing for an average country's cargo. In general, transport costs are found to be additive, and not of the iceberg-type (see Hummels and Skiba, 2004, and Irarrazabal *et al.*, 2015). However, this does not mean that prices do not differ across shipped commodities and destinations.[18]

What about reported import prices? In a setup in which exporters have to use linear pricing, prices will be set such that they will maximize the profit of the exporter, taking into account the additional costs of a tariff and the freight rate. It is then relatively easy for customs authorities to check whether the reported import price is consistent with the actual export price: they could, in principle, compare the sales price with the import price documentation. However, this exercise is much more difficult if a nonlinear pricing scheme is employed and exporters and importers are organized in some form of vertical partnership. For this case, it does not matter whether they are vertically integrated or independent partners, as long as they can find other ways of sharing potential profits than by linear pricing. There is a lot of empirical evidence that the value of imports is under-invoiced to save on tariff duties.[19] This possibility has also been acknowledged by the World Trade Organization, and the WTO Agreement on Implementation of Article VII of the GATT in 1994, that followed the Uruguay Round, sets out rules how imports should be valued. The basic principle is the transaction value that is accepted in case of related partners only if an importer can demonstrate that the vertical partnership did

cartelization easier, since punishment is more severe as there is no room for renegotiations. The US Ocean Shipping Act Reform Act (OSRA) in 1998 allowed long-term contracts to be confidential (see Fusillo, 2013). The North Europe–US conference was the Transatlantic Conference Agreement (TACA) that was abandoned just before the EU Commission abolished the Block Exemption for ocean liner shipping in October 2008.

[18] Ardeleany and Lugovskyyz (2017), using firm-level data from Chile, find that carriers do not only price-discriminate based on the product price, but also based on the size of the shipment.

[19] See Bernard *et al.* (2006), Bhagwati, J. (1964, 1967), Buehn and Eichler (2011), De Wulf (1981), Das *et al.* (2016), Ferrantino *et al.* (2012), Fisman and Wei (2004), Javorcik and Narciso (2008), Liu *et al.* (2016), McDonald (1985) and Swenson (2001). A part of this literature studies the incentives to under-report the value of exports from China as the Chinese value added tax is not completely refunded at the Chinese border.

not influence the price.[20] Since most of the importing countries in our dataset were WTO members in 1995 or became members later on, we may assume that these procedures are more or less followed, but it should be clear that there is much more discretion for exporters and importers in case of nonlinear pricing schemes.

In maritime transport, over- or underreporting of volumes seems to be much more difficult as documentation requirements are substantial: each shipment must be documented by the bill of lading, and each ship must have a "manifest", that is, a collection of information from all the bills of lading. Consequently, carriers in maritime shipping should know precisely the type of their shipments.[21] The shipping line will verify that the cargo description and other information shown on the import or export declaration to customs authorities is the same as that is shown on the line's bill of lading. This is especially important when the shipment is in containers. When carriers know the value and the weight of the shipment, they can price-discriminate across products and destinations.[22] While misreporting of import volumes is not completely impossible as carriers have to rely on the information provided by the shipper to some extent, the shipper runs the danger that customs authorities cross-check the manifest and customs declarations. Furthermore, underreporting would also imply underinsurance.[23]

[20]See Agreement on Implementation of Article VII of the General Agreement on Tariffs and Trade 1994 (Customs Valuation Agreement), https://www.wto.org/english/res_e/booksp_e/analytic_index_e/cusval_01_e.htm, accessed November 16, 2017. If the customs authorities are in doubt of the applicability of the transaction value, (i) they may ask the importer to provide further information, (ii) and in case of no or no sufficient response, they will conclude that the value cannot be determined using the transaction value. In this case, other methods must be applied in a prescribed hierarchical order.

[21]The bill of lading also has the purpose of proving evidence to the importer that the goods have been received by the carrier and are carried

[22]In case of Full Container Load (FCL) cargoes, that is, full container shipments that are used by a single costumer only, the shipping line or any agent is not privy to the packing of the containers or the nature of the cargo that is inside the containers. Misreporting is possible in terms of value, but would be fraudulent on the part of the exporter. However, any misreporting in terms of weight and measurement would immediately be detected.

[23]The corruption literature focuses on options to falsify product codes and the under-reporting of volumes, and Sequeira (2016) finds that corruption implies mostly a misrepresentation of import levels. We will not consider volumes, but will focus on the pricing behavior and the reported prices, as we are interested in how tariff changes affect export price behavior and freight rates, given potential misinvoicing. In what follows we will thus focus on the reported export prices that, together with the tariff and the freight rates, will determine the import price.

What do we take away from our analysis of transport markets and reported prices? First, transport markets are dominated by independent carriers that may have market power and operate under substantial economies of scale. Second, we will have to model potential discretion in terms of import value declarations and how this behavior will change with tariff changes if exporters and importers are not confined to linear pricing. The next section will develop a simple model that can accommodate both linear and nonlinear pricing, and section 4 will show that the response of export prices to tariff changes can be explained only in a nonlinear pricing setup.

3 Theoretical Framework

Consider a profitable export activity x that can create a certain net revenue in the importing country; this net revenue is the difference between sales and all local costs after the import price, the freight rate and the tariff duties have been paid for. This export activity can be in the form of an intermediate or a final good and will be subject to an ad valorem import tariff τ.[24] Whatever the details of this export activity are, we keep our model as general as possible and assume that it will generate a net revenue of size $R(x)$ in the importing country where $R_x(0) > 0$ and $R_{xx}(x) < 0$.[25] For example, if the import good can be turned into one unit of the final good for a constant marginal cost $\gamma, \gamma \geq 0$, $R(x) = (p(x) - \gamma)x$ where $p(x)$ denotes the residual inverse demand function that the importer faces. If the import good is an intermediate input, the net revenue is given by $R(x) = \max_z p(y(x, z))y(x, z) - w \cdot z$ where $y(x, z)$ is the production function that depends on the intermediate input x and on a vector of other inputs, denoted by z; w denotes the vector of the respective factor prices. The outcome will depend on how export prices and freight rates will be determined.

As for the transport market, carriers have to build up capacity, either in terms of a schedule for liner shippers or in terms of vessel capacity for bulk carriers, and they have to set their freight rates before other parties arrange all trans-boundary transactions. Consequently, we start our analysis with the carrier. As the last section has demonstrated,

[24]We chose the ad valorem tariff in our model as nearly all of the tariffs in our database are of this type.

[25]Throughout the paper, subscripts denote (partial) derivatives.

the carrier is an independent agent and may have market power. At the same time, empirical evidence suggests that the transport sector may feature strong economies of scale, so an increase in transport volume may result in a decline in unit transport costs as carrying more units allows for better use of transport capacities and/or a substantial reduction in handling costs in ports and on vessels. In Appendix A.1, we present the details of a model featuring a monopolistic carrier.

In this simplest model of a monopolistic carrier, the carrier will correctly anticipate, at least in expected terms, how export volumes will respond to freight rates. In particular, this carrier faces some (residual) demand for freight services for a particular good. Suppose that the tariff is reduced, leading to an increase in x and $R(x)$ as the export activity has become more profitable. Two effects materialize: on the one hand, the export market has become more attractive, so the carrier has an incentive to increase the freight rate to benefit from trade liberalization if his market position allows him to do so.[26] If the carrier already runs close to the capacity limit or building up capacity is costly, this incentive will be even larger. On the other hand, if the carrier has a lot of spare capacity or building up capacity is cheap, shipping will become more efficient, and if this effect is strong enough, the carrier will decrease the freight rate, and tariffs and freight rates both decline.

We can think of a lot of extensions to this basic model of the transport market, and we may wonder how our results extend to a setting of oligopolistic competition. In Appendix A.1, we generalize our approach using a Salop model of product differentiation among carriers. We show that our main result continues to hold: how the freight rates changes depends on the relative strength of the marker power effect versus the potential economies of scale effect. Additionally, freight rates may also decline with falling tariffs because they are strategic complements in a price competition model. More complex models will not change our basic result which we summarize in

Proposition 1. *For all organizational modes, the effect of the tariff on the freight rate is ambiguous.*

Proof. See Appendix A.1. □

[26] Due to double marginalization, this effect would at least partially compensate for the tariff effect. There is also related literature on private contractual arrangements replacing institutional barriers to trade, see for example Raff and Schmitt (2006).

Note carefully that Proposition 1 holds for all organizational forms of export and import activities as we will discuss them.[27] Of course, export levels x will differ across organizational modes, but we can conclude that strong economies of scale may imply a co-movement of tariffs and freight rates. In this case, the gains from trade liberalization are supplemented by an efficiency gain in the transport industry that is able to utilize capacities more efficiently, and this effect overcompensates the double marginalization effect.

Let us now turn to the organization of export and import activities. A crucial distinction will be whether the importer and the exporter will be in a vertical partnership or not, that is, whether they can work out an arrangement that does not have to rely on linear pricing or whether the exporter arranges exports at arm's length and is thus confined to linear pricing. In the latter case, an independent exporter sells directly to consumers or to a number of local wholesalers and retailers in the foreign country. It is important to note that these transactions are done via a market with a sufficiently large number of buyers, and thus pricing must be linear due to potential arbitrage and market clearing conditions.

The independent exporter is responsible also for the trans-border transaction and will have to arrange transport by himself. This is the classical trade model of a firm selling directly to a large number of customers in an importing country. Consider an independent exporter that is facing the market in the importing country in which his market power is determined by the respective residual demand such that the net revenues are the residual market demand $R(\cdot) = px(p)$ where p denotes the market-clearing price. In this case, he sells to an anonymous market, anticipating its behavior. The export profit is equal to

$$\pi = \frac{R(x(p))}{1+\tau} - (c + \gamma + \rho)\, x(p), \tag{1}$$

where $\gamma \geq 0$ denotes the transaction cost of selling through the market in the importing country, and $c > 0$ is the marginal production cost. ρ denotes the freight rate, and τ denotes the ad valorem tariff.[28] As it is well-known, the pricing behavior in terms of the

[27] We show the details for the case of an independent exporter in Appendix A.2. Appendix A.3 and Appendix A.5 show that Proposition 1 also holds for the case of mill pricing and for a vertical partnership, respectively.

[28] Note that the transboundary freight costs are excluded from the tariff base such that only the FOB value is subject to the tariff.

consumer price is determined by

$$p^* = \frac{\epsilon(\cdot)}{\epsilon(\cdot) - 1}(1 - \tau)(c + \gamma + \rho). \tag{2}$$

where $\epsilon(\cdot) > 1$ denotes the elasticity of the residual demand $x(p)$ in the importing country in absolute terms. In line with the literature, we assume that $\epsilon_x(\cdot) \leq 0$ holds, that is, that the elasticity of demand increases with a reduction in consumption.[29] Export prices will be denoted by q, and since the export (FOB) price is given by $q = p/(1 + \tau) - \rho$, the optimal export price is equal to

$$q^* = \frac{\epsilon(\cdot)}{\epsilon(\cdot) - 1}(c + \gamma + \rho) - \rho. \tag{3}$$

We find:

Proposition 2. *In the case of linear pricing, an increase in the tariff will lead to a decrease in the export price. The effect of freight rate changes on the export price is ambiguous.*

Proof. Differentiation q^* (see (3)) w.r.t. τ yields $q^*_\tau = -\epsilon_x(\cdot)x^*_\tau(c+\gamma+\rho)/(\epsilon(\cdot)-1)^2 \leq 0$, and differentiation of q^* w.r.t. ρ yields $q^*_\rho = -\epsilon_x(\cdot)x^*_\rho(c+\gamma+\rho)/(\epsilon(\cdot)-1)^2 + 1/(\epsilon(\cdot)-1)$ where - $\epsilon_x(\cdot)x^*_\rho(c+\gamma+\rho)/(\epsilon(\cdot)-1)^2 \leq 0$ and $1/(\epsilon(\cdot)-1) > 0$. □

We find that an independent exporter will decrease the export price in response to a tariff increase as $\epsilon_x(\cdot) \leq 0$ implies that the pass-through of the tariff is incomplete. The effect of a freight rate increase is ambiguous and depends on the pass-through of cost increases versus the reduction in the FOB price. We can show that the tariff effect can also be observed in a mill pricing model in which a firm produces intermediate or final goods, and an importer will source these goods from this supplier. The main difference is that this supplier is active on a market in the exporting country: she will offer final or

[29]For details, see Feenstra (2015), Chapter 7. Most demand functions fulfill $\epsilon_x(\cdot) \leq 0$ which implies that demand is not more convex than a constant-elasticity demand function. CES demand functions are isoelastic and thus the limiting case. Mrázová and Neary (2017, 2018) label all demand functions that are more convex than CES superconvex, and all others subconvex. They argue that superconvexity cannot be ruled out for all demands (see footnote 10 in Mrázová and Neary, 2017), but it seems that subconvexity is an appropriate assumption on average.

intermediate goods on this market to importers from other countries, and possibly also domestically. We deal with this case in Appendix A.3 and show that the response to the tariff is qualitatively the same.

Furthermore, we show in Appendix A.4 that our results also extend to the case in which firms compete with different qualities or a firm offers different qualities. It is well known from the "Washington apples" effect (see Hummels and Skiba, 2004) that tariffs may increase the relative demand for high-quality goods when export prices do not change with tariffs. More recently, differences in the quality of output have been identified as being important for the gains from trade (see, for example, Fan *et al.* 2015, 2017, 2018). It has also become clear from this literature that prices respond differently to trade barriers depending on the quality of output. While the strength of the price response within a product group depends on quality and firm productivity, our analysis is concerned with the overall change in export prices with tariffs. Appendix A.4 shows in a simple model that export prices for both a low- and a high-quality good should also decline with tariffs when low- and high-quality goods are traded at arm's length.[30] Thus, if we consider a product group, we should also expect the average price or the price index to fall with tariffs. Consequently, the hypothesis from this analysis is that the effect of the tariff on the export price should be significantly negative.

We now turn to the case in which the exporter and the importer are in a vertical partnership. In this setup, partners are not confined to linear pricing. For our purpose, it is not important whether the two partners belong the same legal entity, have some cross-ownership or are legally independent. A vertical partnership can encompass many equity arrangements. It is, however, important that the partners have a contractual arrangement that allows them to go beyond arm's-length-trade. These contracts may be subject to hold-up and moral hazard problems and thus incomplete. We model this incompleteness by assuming that the cost function can be marginally increasing: $C(x)$ with $C_x(x) > 0, C_{xx}(x) \geq 0$. Whatever the source of incompleteness, it is well-known that these frictions lead to less than optimal arrangements, and $C_{xx}(x) > 0$ may reflect that a more ambitious partnership has to carry some extra costs. Furthermore, it may also be the result of payout arrangements that become more difficult to organize and to guarantee the more ambitious

[30] In fact, we also find a "Washington apples" price effect as the reduction in the high-quality export price is larger in absolute terms than the decline in the low-quality export price. See Appendix A.4.

the partnership is.

For our analysis, it does not matter how contracts are designed in detail. We assume that the partners maximize the joint profit of a vertical partnership subject to several constraints implying $C(x)$. A crucial aspect of this partnership is the role of the export price. Since the partners have other means to arrange their payouts than linear pricing, the export price takes over the role of a transfer price. More specifically, a partnership has to report to customs authorities that the export of size x has some unit value of size q, leading to a tariff duty of τqx, and thus the partnership has a strong incentive to under-report the export price.[31] The export price does not matter for a zero tariff, as it cancels out from aggregate profits of the partnership. For $\tau > 0$, the cost for the partnership is equal to τqx.

If the partnership were free to choose the export price, it would set $q = 0$ as to avoid any tariff payment. This is, of course, not a realistic option as customs authorities will not accept a declared zero value import; they are likely to apply the procedures according to the WTO guidelines as they have been discussed in the last section. The partnership will have to declare the product code of the good, and the customs authorities will have an idea about the possible prices for which these goods are usually traded. We will assume that a reference price $\tilde{q}$ exists and the partnership will not have to carry an additional cost if it declares an export price smaller than $\tilde{q}$. If it claims that the export price is smaller, it will have additional costs that summarize all administrative and legal costs that could arise from concealing the true value and claiming a lower value.[32] In particular, we assume that the partnership will maximize its profit given by

$$\Pi = R(x) - (\tau q + \rho)\, x - C(x) - \Delta(q), \tag{4}$$

[31] That a vertical partnership changes the pricing incentives is not a new insight, see, for example, Keuschnigg and Devereux (2013). The innovation here is the interaction with the ad valorem tariff.

[32] The different measures to determine an accepted import price may lead to an implicit price range such that the customs authority will accept any quoted price in this range without further investigation. In our setup, only the lower bound is a relevant constraint. However, note that explicit price range systems (PRS) are not compliant with WTO rules. Guatemala successfully challenged Peru's PRS in 2014 also on the ground that it prescribes a minimum import price. Thus, our modeling approach of a marginally increasing concealment cost seems sensible.

where

$$\Delta(q) = \begin{cases} 0 & \text{if} \quad q \geq \tilde{q}, \\ > 0 & \text{if} \quad q < \tilde{q}. \end{cases} \tag{5}$$

$\Delta(q)$ is the concealment cost function for which $\Delta_q(q) < 0, \Delta_{qq}(q) > 0$ holds if $q < \tilde{q}$.[33] The concealment cost function implies that the marginal concealment cost increases with under-invoicing. Furthermore, we assume that

$$\zeta(q) = -\frac{d\Delta_q(q)/\Delta_q(q)}{dq/q} > 1$$

holds for $q < \tilde{q}$: a decrease in the reported price q by 1% increases the marginal concealment cost by more than 1% which will imply a normal response of exports to tariffs, that is, a decline with τ. The partnership now has two strategic variables, x and q, and the first-order conditions are given by

$$\begin{aligned} R_x(x^{**}) - q^{**}\tau - \rho - C_x(x^{**}) &= 0, \\ -\tau x^{**} - \Delta_q(q^{**}) &= 0. \end{aligned} \tag{6}$$

We find:

Proposition 3. *In the case of a vertical relationship, an increase in the tariff rate τ has an ambiguous effect on the export price. An increase in the freight rate leads to an increase in the export price.*

Proof. See Appendix A.5. □

Proposition 3 shows that the effect of the freight rate on the export price is now unambiguous: when the freight rate increases, exports become more expensive and will be reduced, and thus the endeavor to reduce q becomes less profitable. The impact of the tariff, however, is ambiguous. The reason is that the export price is a transfer price now, and the partnership has to balance the marginal costs of reducing this transfer price

[33] Concealment cost functions have been used in the public economics literature on corporate taxation and transfer pricing, see for example Haufler and Schjelderup (2000), and Nielsen *et al.* (2008, 2010, 2014). Kant (1988) uses an approach in which under-invoicing can be detected with a certain probability, leading to a penalty. This approach is strategically equivalent to a concealment cost approach.

successfully with its marginal benefits. On the one hand, an increase in the tariff makes reducing q more profitable as $q\tau$ has gone up per unit of exports. On the other hand, the tariff will reduce exports, making the reduction in q less effective as the export volume will be smaller, so the overall effect is not clear. However, the level of exports will decrease with a tariff increase, irrespective of the response of the export price, as a tariff increase will increase the cost of exporting.[34]

In summary, we have arrived at a clear prediction from our models of trade: the effect of the tariff rate on the export price of the vertical partnership is ambiguous, while the independent exporter will decrease the export price if the tariff rate goes up. For both cases, the effect of the tariff rate on the freight rate depends on the potential strength of the economics of scale in the transport industry. We now turn to our empirical analysis and show that only the vertical partnership model is consistent with our data.

4 Data and Empirical Results

For our empirical exercise, we create a rich dataset by combining three main data sources. First, our baseline dataset is the OECD Maritime Transport Costs database, the most comprehensive dataset on maritime transport rates known to date. This database contains annual data on freight rates for 44 importer countries, 228 exporter countries and more than 6,000 commodities at the 6-digit HS classification.[35] As discussed in Section 2, our focus on maritime costs is well justified by the fact that the largest fraction of world trade is seaborne.[36] The maritime transport cost data are either directly taken from the original

[34] In Appendix A.5, we show that our result does not depend on our specification that the concealment cost depends on the quoted price only, but also holds true if we make the concealment cost function more general such that it depends on import levels as well. Our results do also not change if we make this cost function even more complex, for example, if costs also depend on the efforts of the customs authorities. Furthermore, there may be additional incentives to under-report import values, for example, to reduce corporate tax payments, and Appendix A.5 discusses such an extension as well.

[35] The data are collected at the country of destination (importer) and contains transport cost data for all countries the importer trades with, explaining the difference between the number of importers and the number of exporters. For more information see https://stats.oecd.org/Index.aspx?DataSetCode=MTC and Korinek (2011).

[36] In 2004, approximately 50% of trade by value traveled by sea; the share increases to about 95% when measured in service units (kg-km). See Cristea *et al.* (2013) for a detailed provision of data on trade shares by transport mode for different regions in 2004.

customs data or estimated at the product level from carriers' actual rates, if data is only available at more aggregated levels. It covers different modes of maritime shipment such as bulk carriers, tankers or containers, and reports two different cost measures: unit costs and ad valorem equivalents between country pairs at the 6-digit (HS) commodity level.[37] Second, we obtain information on international trade, particularly on export prices and trade volumes, from the UN Comtrade Database. Finally, information on tariffs is taken from the UNCTAD TRAINS database. Both, the Comtrade- and the UNCTAD TRAINS database also provide annual importer-exporter specific data at the 6-digit HS commodity classification, which allows for uniquely matching all datasets.

After matching and cleaning the data of obvious errors,[38] the combined dataset covers the time period of 1991 to 2007 and contains about 2.25 million observations for 38 importing countries from 155 countries of origin for 4,809 different products at the detailed 6-digit commodity level (HS1988).[39] The data primarily include manufacturing products (around 90%), but also primary products such as raw materials and agricultural goods. The data constitute an unbalanced panel; data for a particular country may not be available in each of the three datasets for every year and commodities may not be traded among the same importer-exporter pairs every year.

Our dataset covers a time period that is characterized by decreasing import tariffs for almost all importers – not least triggered by the Uruguay Round that came into effect in 1995 with deadlines ending in 2000. Figure 2 shows the average tariff over all imported goods for a number of countries in our dataset. The average import tariffs for the 38

[37]Unit costs are usually measured as the price per kilogram, i.e., the price in USD that has to be paid in order to ship one kilogram of a particular good from country A to country B. Ad valorem equivalents are total transport costs for a particular product divided by its import value.

[38]This for instance includes dropping observations for which either transport cost, tariff or trade data are missing or for which values are obviously erroneous (e.g. negative transport cost).

[39]The importing countries include Algeria, Argentina, Australia, Bangladesh, Bolivia, Brazil, Chile, China, Colombia, Ecuador, Egypt, European Union as an aggregate, Hong Kong, India, Indonesia, Japan, Jordan, Korea, Malaysia, Mexico, Morocco, New Zealand, Pakistan, Paraguay, Peru, Philippines, Russia, Saudi Arabia, Singapore, South Africa, Sri Lanka, Thailand, Tunisia, United Arab Emirates, United States, Uruguay, Venezuela and Vietnam. The OECD data only contain information for the EU15 as a single custom union, but not for each of its member states separately. Countries covered include Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom. In order to obtain tariff and trade data that match the transport cost data, weighted averages with import values as the weight are used to aggregate tariffs (TRAINS), export prices and trade volumes (both Comtrade) from country level to the EU15 level.

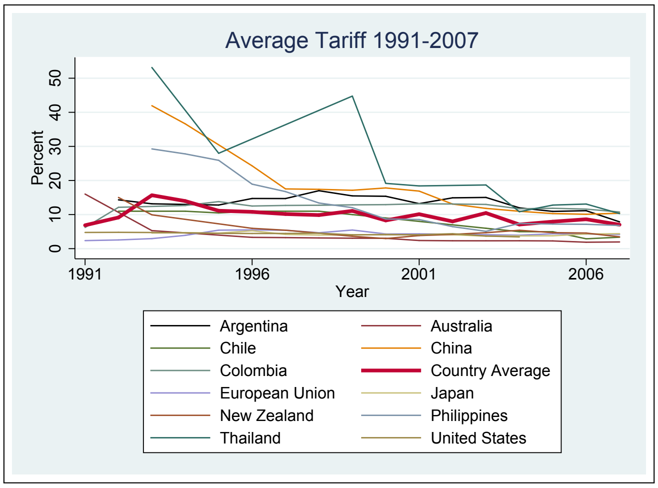

Figure 2

importing countries have decreased from 15.56% to 6.58% from 1993 to 2007 (thick red line).[40] The largest decreases can be identified for the middle-income countries in our sample, especially for Asian countries. For instance, from 1993 to 2007, the average tariff has dropped by 22.52 percentage points to 6.74% in the Philippines, by 30.94 percentage points to 10.05% in China and by 41.55 percentage points to 9.99% in Thailand. Average tariffs for high-income countries have fallen at much lower rates or have remained at a stable level as the rate in the base year is already comparably low. In the US, for instance, average tariffs have decreased from 5.16% in 1991 to 2.68% in 2007, and in Japan, average tariffs have dropped from 4.51% to 3.73% during the same time period. Despite the general downward trend, there is substantial variation across goods, countries and time.

During the same time period, transport costs have also declined. On average, unit transport costs have declined from around 0.5 USD per unit in the early 1990's to around 0.3 USD per unit in the later 2000's (see Figure 3). Contrary, average export prices

[40]Note that the average import tariff is not computed here as an average over all product-specific import tariffs independent from the importing country, but as the average of the countries' average import tariffs. Accordingly, every country contributes equal shares for the calculation of the average tariff, despite the fact that larger countries such as the US or the EU account for the majority of observations. For the first two years, almost only tariff data from highly industrialized countries (that generally have lower import tariffs than less industrialized countries) is available, which explains lower average tariff rates for these years.

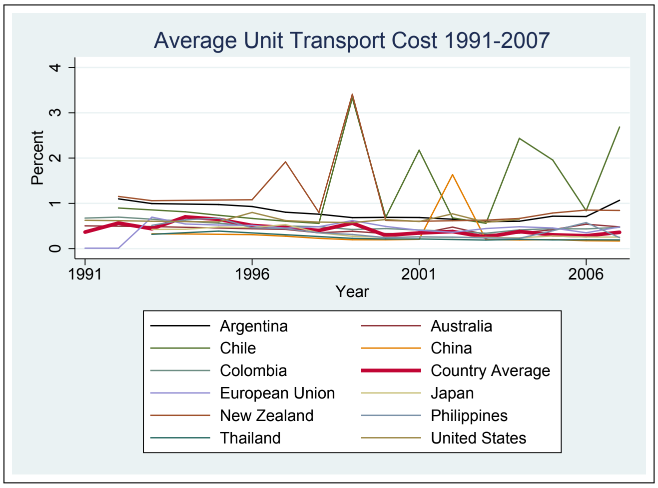

Figure 3

show no clear pattern (see Figure 4). For both transport costs and export prices, we find substantial variation over time and across countries as well.

We now use these data to test for the relationship between tariffs, freight rates, and export prices. We use high-dimensional fixed effects in order to take out any variation in freight rates and export prices that may originate from product-, importer- and exporter-related shocks over time. In particular, we will control for any effect that comes about from demand and supply shocks, including those affecting transport, and from the specific relationship between a certain exporter and importer for a certain good. First, we test for the effect of tariff changes on the transport costs by running the following two regressions:

$$lnTransportcost_{ijnt} = \alpha + \beta_1 lnTariff_{ijnt} + c_{ijn} + d_{it} + e_{jt} + f_{nt} + u_{ijnt}, \quad (7a)$$

$$lnTransportcost_{ijnt} = \alpha + \beta_1 lnTariff_{ijnt} + d_{int} + e_{jnt} + u_{ijnt}, \quad (7b)$$

where $lnTransportcost$ are the logarithmized transport costs (either measured as unit value or ad valorem) between importer i and exporter j for product n at time t and $lnTariff$ are the logarithmized effectively applied tariffs.[41] Note that our specification

[41] To estimate elasticities, the effectively applied tariffs are defined as $ln(1+tf)$, where tf is the decimal tariff rate.

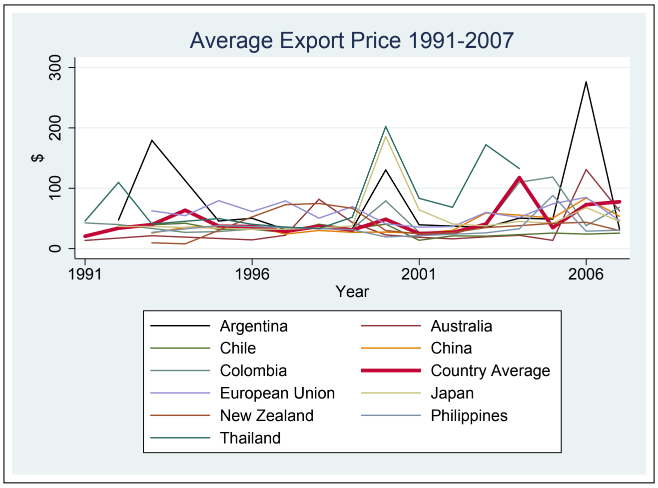

Figure 4

takes into account the potential backhaul problem as the freight rates for a good n may, in general, differ for the export from i to j as compared to the export from j to i.[42] In equation (7a), c_{ijn} are importer-exporter-good triple fixed effects that control for any variation from cross-border sales for a specific good from country i to country j. This fixed effect should, among other things, also absorb any variation that is due to the effect of distance on product quality.[43] d_{it}, e_{jt} and f_{nt} are importer-time, exporter-time and product-time double fixed effects, respectively, and they control for demand and supply shocks within the importing and exporting country and any global product shock; u_{ijnt} is the error term. To address the concern that our results could be driven by product-specific shocks that are not global but country-specific, we run a second regression, given by equation (7b), in which d_{int} are importer-good-time triple fixed effects, and e_{jnt} are exporter-good-time triple fixed effects.[44] We apply the product fixed effects at the 6-digit

[42]Figueiredo De Oliveira (2014), Friedt and Wilson (2017), Jonkeren *et al.* (2011), Márquez-Ramos *et al.* (2011) and Wong (2017) show that trade imbalances affect freight rates.

[43]For example, Baldwin and Harrigan (2011), Bastos and Silva (2010), Manova and Zhang (2012) and Helble and Okubo (2008) find that distance and product quality are positively correlated.

[44]These fixed effects should also control for any positive correlation between unit values and product quality on a product level, see Verhoogen (2008), Manova and Zhang (2012), Kugler and Verhoogen (2012), Crozet *et al.* (2012), and Feenstra and Romalis (2014).

product level.[45] For all regressions, we apply heteroskedasticity robust standard errors clustered by importer, exporter, and product. This choice of clustering is not only very conservative but also well justified by our setup.[46]

We like to emphasize that our first specification (always labeled with "a") controls for unobserved time-invariant importer-exporter-product attributes and time-variant importer, exporter and product attributes, whereas the second specification (always labeled with "b") controls for importer-product trends and exporter-product trends. Thus for the first specification, the only remaining identifying variation originates from transport cost changes differentiated by origin-destination-product adjusted for importer trends, exporter trends, and product trends. In the second specification, the variation is caused by differences between importer-exporter pairs. Specification (7a) and all following specifications employing the same fixed effects assume that the supply- and demand-side variation – that the fixed effects should control for – is given by import-export-product differences, and by exporter-, importer- and product shocks over time. Specification (7b) and all following specifications employing the same fixed effects assume that the supply-side and demand-side variation is given by demand import and export supply shocks for each product over time. Note that these fixed effects control for all changes in supply due to technology changes in production and transport and for changes in demand due to changes in preferences.

Despite our choice to include high-dimensional fixed effects, we find positive and significant effects of tariff changes on transport costs both when measured in unit values and ad valorem.[47] The results are shown in Table 1. The coefficients for tariffs are positive and significant for both equation (7a) and (7b) independent from the transport cost measure, indicating strong economies of scale in the transport industry.[48] Transport costs measured

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[45] All equations are estimated using the STATA reghdfe command (Correia, 2016) that is well suited for large datasets with high-dimensional fixed effects.

[46] The fact that our data is collected at the individual product, year, importer, exporter level, whereas the fixed effects represent cluster of units rather than individual units, stresses the necessity to cluster; see for instance Abadie *et al.* (2017).

[47] There are 301,967 different importer-exporter-product pairs, which implies that on average each of the triple fixed effects contains around 7.1 observations.

[48] We have also conducted several robustness checks for all estimations by dropping observations, for which we cannot rule out some cross-ownership between carriers and large exporters. For all estimations, we conduct separate estimations for manufacturing goods and raw materials and find that the reported

in unit values show the effect of the tariff on freight rates. The ad valorem values can easily be affected by fluctuating import prices, but offer additional information on the share of transport costs in value creation. The unit value estimates in column (1) and (3) imply that a 1% decrease in the effectively applied tariff is associated with a decrease of 0.04% (column 1) and of 1.98% (column 3) in the unit value transport costs. Additionally, the significant positive effects in ad valorem terms show that even the share of transport costs declines with a decline in the tariff rate.

Table 1: Tariffs and Transport Costs

	(1)	(2)	(3)	(4)
Equation	(7a)	(7a)	(7b)	(7b)
Transport Cost Measure	Unit Value	Ad Valorem	Unit Value	Ad Valorem
ln Tariff	0.0383**	0.1475**	1.9827***	1.8451**
	(0.0171)	(0.0593)	(0.6665)	(0.7044)
Importer-Exporter-Product FE	Yes	Yes	No	No
Importer-Time FE	Yes	Yes	No	No
Exporter-Time FE	Yes	Yes	No	No
Product-Time FE	Yes	Yes	No	No
Importer-Product-Time FE	No	No	Yes	Yes
Exporter-Product-Time FE	No	No	Yes	Yes
Adj. R^2	0.6853	0.6426	0.5783	0.5431
N	2,145,875	2,133,153	1,593,944	1,579,748

Notes: Heteroskedasticity-robust clustered standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The number of observations differs between the two transport cost measures due to randomly missing data.

Note that our dataset is constructed such that we include only tariff and transport cost observations for which we also observe an export price. As such, our results seem to be confined to the intensive margin of international trade. However, we have also estimated equation (7a) and equation (7b) with a larger dataset after only combining the OECD Maritime Transport database and the tariff data from UNCTAD TRAINS. Results remain

findings hold for both types of goods. The details for all robustness checks are available upon request.

largely unchanged (see Appendix A.6), so we may conclude that our results extend to the extensive margin as well.

We cannot do a similar exercise for the effect of tariff changes on export prices as we do not observe (prohibitively) large export prices that imply zero trade, so our analysis is confined to the intensive margin. However, this is completely consistent with our theory for which we have assumed a profitable export activity, to begin with. In particular, we estimate the following equations:

$$\begin{aligned} lnExpPrice_{ijnt} &= \gamma + \delta_1 lnTransportcost_{ijnt} + \delta_2 lnTariff_{ijnt} \quad (8a)\\ &+ c_{ijn} + d_{it} + e_{jt} + f_{nt} + u_{ijnt}, \\ lnExpPrice_{ijnt} &= \gamma + \delta_1 lnTransportcost_{ijnt} + \delta_2 lnTariff_{ijnt} \quad (8b)\\ &+ d_{int} + e_{jnt} + u_{ijnt}, \end{aligned}$$

where the unit value FOB export price *lnExpPrice* is calculated as the total trade value divided by the net weight in kilogram for a given product. Transport costs are measured in unit values. Our empirical strategy is in line with the setup as derived from the theory models, which show that both transport costs and tariffs independently from each other have an effect on export prices. We find that the tariff coefficient is positive, contrary to the independent exporter model, and insignificant in specification (8a) (see Table 2).

We have also conducted multiple multicollinearity checks, but all tests indicate that multicollinearity is not a concern here. Values for the variance inflation factor (VIF) are close to one (and thus well below the rule-of-thumb threshold of ten), and transport costs and tariffs are only weekly correlated (0.1058). Also the condition number does not indicate signs of multicollinearity.[49] While our results suggest that tariffs have both a direct and an indirect effect – via the transport costs – on export prices, we also see clearly that the direct effect, as measured by δ_2, is never negative.

If, as our results suggest so far, economies of scale beat market power in the maritime transport industry, we would also expect to find a negative relationship between trade volumes and transport costs. To test this hypothesis, we estimate the following set of

[49] To be precise, we compute a condition number of 3.51, which is well below any critical values that indicate multicollinearity.

Table 2: Export Prices and Tariffs

	(1)	(2)	(3)	(4)
Equation	(8a)	(8b)	(8a)	(8b)
ln Transport Cost	.	.	0.0463***	0.1105***
	.	.	(0.0000)	(0.000)
ln Tariff	0.01	0.9858***	0.009	0.7533***
	(0.0220)	(0.2439)	(0.0215)	(0.000)
Importer-Exporter-Product FE	Yes	No	Yes	No
Importer-Time FE	Yes	No	Yes	No
Exporter-Time FE	Yes	No	Yes	No
Product-Time FE	Yes	No	Yes	No
Importer-Product-Time FE	No	Yes	No	Yes
Exporter-Product-Time FE	No	Yes	No	Yes
Adj. R^2	0.8415	0.8075	0.8418	0.906
N	1,932,335	1,406,33	1,932,269	1,406,289

Notes: Heteroskedasticity-robust clustered standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

equations:

$$\begin{aligned} lnTradevolume_{ijnt} &= \kappa + \rho_1 lnTransportcost_{ijnt} & \text{(9a)}\\ &+ c_{ijn} + d_{it} + e_{jt} + f_{nt} + u_{ijnt}, \\ lnTradevolume_{ijnt} &= \kappa + \rho_1 lnTransportcost_{ijnt} + & \text{(9b)}\\ &+ d_{int} + e_{jnt} + u_{ijnt}, \end{aligned}$$

where *lnTradevolume* is the logarithmized trade volume measured as the net weight (usually in kilogram) of the exported good provided by the UN Comtrade Database. As expected, we find a negative and significant relationship between trade volumes and unit value transport cost (see Table 3).[50] A 10% increase in the trade volume is associated

[50] Results for trade volume estimates remain largely unchanged when including *lnTariff* as an additional

with a decrease of 0.24% (column 1) and of 0.72% (column 2) in the unit value transport costs.

Table 3: Trade Volumes and Transport Costs

	(1)	(2)
Equation	(9a)	(9b)
ln Trade Volume	-0.0244***	-0.0716***
	(0.0038)	(0.0066)
Importer-Exporter-Product FE	Yes	No
Importer-Time FE	Yes	No
Exporter-Time FE	Yes	No
Product-Time FE	Yes	No
Importer-Product-Time FE	No	Yes
Exporter-Product-Time FE	No	Yes
Adj. R^2	0.6907	0.5832
N	1,932,270	1,406,291

Notes: Heteroskedasticity-robust clustered standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

As a further robustness check we also run all regressions separately for the three different transport modes containers, tankers and bulk carriers, where containers are the dominant mode of maritime transport, see Appendix A.7. We see that that our results are also confirmed at the transport mode level, and surprisingly so even for tankers and bulk carriers. For all transport modes, there is neither any significantly negative effect of tariffs on freight rates nor on export prices, and we also find a negative and significant relationship between trade volumes and unit value transport cost for each transport mode. In conclusion, we find that the maritime transport industry has featured strong economies of scale that have supported trade liberalization by a reduction in freight rates.[51] Fur-

explanatory variable similar to our equation (8a) and equation (8b).

[51]Other transport sectors, like air transport, might not experience any increasing returns to scale. Hummels and Schaur (2010) investigate air transport and maritime shipping as competing transport modes.

thermore, our finding on the behavior of export prices is consistent only with the vertical partnership model as export prices either increase with tariffs or remain uninfluenced by the tariff rate on average.

5 Concluding remarks

This paper has shown that maritime transport costs and tariffs have co-moved. As maritime transport is cartelized and monopolized to some extent, the only explanation for this co-movement are strong economies of scale. On average, carriers had spare capacity or could build up capacity cheaply and could thereby handle additional freight much more efficiently. Thus, it is obvious that the role of the transport industry has to be reconsidered as it seems inappropriate to assume that the resource costs of trade are constant. Furthermore, we are able to show that the impact of the tariff on export prices is not clear. Only our vertical partnership model can explain this empirical pattern.

Since maritime transport implies long distance and sea travel and vertical partnerships are more likely for exports relying on road and rail transport, our setup was stacking the deck against this organizational form. However, as we could show, even for maritime transport, it seems that the vertical partnership model is on average the dominating organizational form. Our results are consistent with the observation that a large part of international trade is of the intra-firm type, that is, within firm boundaries of a multinational enterprise (for a recent contribution, see Corcos *et al.*, 2013). At the same time, however, Ramondo *et al.* (2016) find for US multinationals that only a very small number of affiliates are involved in intra-firm trade. Our analysis thus also indicates that vertical partnerships seem to be prevalent, may go beyond firm boundaries and may also cover inter-firm trade.

Our results also show that the standard model of trade, assuming an independent seller, is not the model our data can support. Our empirical analysis has considered the pre-crisis period from 1991 until 2007, with the advantage that our empirical investigation does not include the global financial crisis that has hit trade volumes hard. However, there is no reason to assume that technological progress in the form of digitization has stopped from affecting the organization of trade. Our analysis has found that trade was more likely to be organized in vertical partnerships more than ten years ago. Thus, as an emerging literature emphasizes the role of networks in international trade and with the increased availability and proliferation of technologies that are likely to reduce frictions in vertical partnerships, we do expect their role to be even stronger in the recent past and future.

A vertical partnership does not have to rely on linear pricing, and while decreasing freight rates decrease export prices, we cannot report that decreasing tariffs do the same. The export price is a transfer price in vertical partnerships, and a lower tariff may also reduce the under-invoicing incentive. Nevertheless, a tariff reduction will imply an increase in export activities, also in vertical partnerships, due to a reduction in overall export costs, irrespective of the behavior of the export price. But the welfare effects of trade liberalization seem to be more complex in these partnerships, and thus we have to explore in more detail how they are organized to understand the gains from trade. Models based on linear pricing have often found only very modest welfare effects. It would be interesting to explore whether and how vertical partnerships may change these results, but we leave this quantification to future research.

Appendix

A.1 Modeling the transport market

Assume a monopolistic carrier to begin with who maximizes her profit

$$\pi^c = \rho x - G(F, x) - F, \tag{A.1}$$

where ρ denotes the freight rate per unit. $G(F, x)$ is the variable transport cost of shipping x units from the exporting to the importing country when an investment of size F has been made into shipping capacities, where $G_x(\cdot) > 0, G_F(\cdot) < 0, G_{xx}(\cdot) \geq 0, G_{FF}(\cdot) > 0, G_{Fx}(\cdot) < 0$ holds: marginal costs (w.r.t. x) are positive and non-decreasing, and a larger investment F decreases both the variable transport cost and the marginal transport cost. A possible specification that meets these assumptions is $G(F, x) = \theta(F)x$ where $\theta_F(F) < 0$ and $\theta_{FF}(F) > 0$.

The first-order conditions imply $\pi^c_\rho = x + \rho x_\rho - G_x(\cdot)x_\rho = 0$ and $\pi^c_F = -G_F(\cdot) - 1 = 0$, and the second-order conditions require $\pi^c_{\rho\rho} = 2x_\rho + \rho x_{\rho\rho} - G_{xx}(\cdot)x^2_\rho - G_x(\cdot)x_{\rho\rho} < 0$, $\pi^c_{FF} = -G_{FF}(\cdot) < 0$ and $\det(H) = \pi^c_{\rho\rho}\pi^c_{FF} - \pi^{c2}_{\rho F}$, where $\det(H)$ denotes the Hessian and $\pi^c_{\rho F} = -G_{Fx}(\cdot)x_\rho < 0$. Since $\pi_{\rho\tau} = x_\tau + \rho x_{\rho\tau} - G_{xx}(\cdot)x_\rho x_\tau - G_x(\cdot)x_{\rho\tau}$ is ambiguous in sign and $\pi_{F\tau} = -G_{Fx}(\cdot)x_\tau < 0$, we also find that both

$$\rho_\tau = \frac{1}{\det(H)} \left(-\pi_{\rho\tau} \underbrace{\pi^c_{FF}}_{-} + \underbrace{\pi^c_{\rho F}}_{-} \underbrace{\pi_{F\tau}}_{-} \right) \text{ and} \tag{A.2}$$

$$F_\tau = \frac{1}{\det(H)} \left(- \underbrace{\pi^c_{\rho\rho}}_{-} \underbrace{\pi_{F\tau}}_{-} + \pi_{\rho\tau} \underbrace{\pi^c_{\rho F}}_{-} \right)$$

are ambiguous. Even if we expect $\pi_{\rho\tau}$ to be negative, the signs remain ambiguous. Our results become more complex if we extend the model such that n different goods are shipped and costs depend on aggregate shipment, but this complexity will not resolve the ambiguity of equation (A.2).

As a shortcut, we can define a cost function $\Psi(x) = \min_F G(F, x) + F$ for which $G_F(F^*(x), x) + 1 = 0$ and $F^*_x(x) = -G_{Fx}(F^*(x), x)/G_{FF}(F^*(x), x) > 0$ holds: a larger output makes investment in cost-reducing capacity more effective. We find that

$$\Psi_{xx}(x) = G_{xx}(F^*(x), x) + G_{Fx}(F^*(x), x)F^*_x(x) + G_F(F^*(x), x)F^*_{xx}(x) \tag{A.3}$$

is ambiguous in sign, depending on whether capacity enlargement is relatively cheap or relatively expensive. Using $\Psi(x)$ we can rewrite profits as

$$\pi^c = \rho x - \Psi(x), \Psi_x(x) > 0, \tag{A.4}$$

The first-order condition yields

$$\pi^c_\rho = \rho x_\rho + x - \Psi_x(x)x_\rho = 0, \tag{A.5}$$

and the cross-derivative w.r.t. the tariff is given by

$$\pi^c_{\rho\tau} = x_\tau + \rho x_{\rho\tau} - \Psi_x(x)x_{\rho\tau} - \Psi_{xx}(x)x_\rho x_\tau, \tag{A.6}$$

and its sign can be both positive or negative. We now use this shortcut to discuss an extension to an oligopolistic transport market.

For this purpose and in order to allow for the complexities of product differentiation in transport markets, we assume a Salop circle with its circumference normalized to unity. An exporter will be at a certain location, and the distance to a carrier is an inverse measure of the match quality of the carrier for shipping exports to their destination. An exporter will learn its location after freight rates have been set, and the location probability is uniformly distributed along the circle. The carriers are located in equal distance on the circle,[52] as they offer transport that may be a good or bad match for the exporter. Without loss of generality, let us consider carrier i whose location we normalize to zero. Thus, when n carriers compete, moving rightwards, the neighboring rival is located at location $1/n$, and the other neighboring rival is also $1/n$ away on the left at location $(n-1)/n$. The cost of the mismatch is the distance from the next carrier times a cost t per unit. This mismatch is due to an inconvenient schedule, an inconvenient shipping route to the destination of exports, etc. The market for carrier i is between location $(n-1)/n$ and $1/n$, and we will focus on symmetric equilibria. The exporter $\bar{y}$ that is indifferent between carrier i and the one located at location $1/n$ is given by

$$\rho_i x(\rho_i, \cdot) + t\bar{y} = \rho_j x(\rho_j, \cdot) + t\left(\frac{1}{n} - \bar{y}\right)$$

such that all exporters located between 0 and $\bar{y}$ will use carrier i, and those located between $\bar{y}$ and $1/n$ will use the other carrier. The exporter will want to minimize the sum of freight charges and mismatch costs, and the one located at $\bar{y}$ carries the same total cost with both carriers. The model is thus an extension of the standard Salop model with an export-dependent cost component.[53] Since the exporter draws her location from a uniform distribution, and since the same market exists to the left for carrier i, the probability of winning the exporter is given by

$$\text{Prob}(\rho_i, \rho_j) = \frac{1}{n} - \frac{1}{t}\left(\rho_i x(\rho_i, \cdot) - \rho_j x(\rho_j, \cdot)\right),$$

where ρ_j denotes the (symmetric) price of the rival right and left of carrier i. Note that

$$\frac{\partial \text{Prob}(\rho_i, \rho_j)}{\partial \rho_i} = -\frac{1}{t}\left(\rho_i x_{\rho_i}(\rho_i, \cdot) + x(\rho_i, \cdot)\right) < 0,$$

as long as the marginal revenue is positive; this derivative does not depend on ρ_j. The same is true for

$$\frac{\partial \text{Prob}(\rho_i, \rho_j)}{\partial \rho_j} = \frac{1}{t}\left(\rho_j x_{\rho_j}(\rho_j, \cdot) + x(\rho_j, \cdot)\right) < 0$$

[52]If the location of carriers was endogenous, it is straightforward to show that this would also be their equilibrium location as the Principle of Maximum Product Differentiation applies here. Furthermore, the capacity investment F will determine n in this setup. Note that we model F as private information such that all carriers form expectations on the capacity investment of rival carriers. Otherwise, F would also be strategic in nature and would serve as a commitment device to influence price competition. An extension to strategic investment will not change our ambiguity result.

[53]The Salop model has been extended to flexible demand, see for example Gu and Wenzel (2012) and the cited literature.

for a positive marginal revenue. The effect of a tariff depends on the difference in costs:

$$\frac{\partial \text{Prob}(\rho_i,\rho_j)}{\partial \tau} = -\frac{1}{t}\left(\rho_i x_\tau(\rho_i,\cdot) - \rho_j x_\tau(\rho_j,\cdot)\right).$$

Furthermore,

$$\frac{\partial^2 \text{Prob}(\rho_i,\rho_j)}{\partial {\rho_i}^2} = -\frac{1}{t}\left(\rho_i x_{\rho_i\rho_i}(\rho_i,\cdot) + 2x_{\rho_i}(\rho_i,\cdot)\right)$$

and

$$\frac{\partial^2 \text{Prob}(\rho_i,\rho_j)}{\partial \rho_i \partial \tau} = -\frac{1}{t}\left(\rho_i x_{\rho_i\tau}(\rho_i,\cdot) + x_\tau(\rho_i,\cdot)\right).$$

The expected profit for carrier i is given by

$$\pi^i(\rho_i,\rho_j) = \text{Prob}(\rho_i,\rho_j)\left[\rho_i x(\rho_i,\cdot) - \Psi(x(\rho_i,\cdot))\right].$$

The first-order condition is given by

$$\begin{aligned}\frac{\partial \pi^i(\rho_i,\rho_j)}{\partial \rho_i} &= \frac{\partial \text{Prob}(\rho_i,\rho_j)}{\partial \rho_i}\left[\rho_i x(\rho_i,\cdot) - \Psi(x(\rho_i,\cdot))\right] \\ &+ \text{Prob}(\rho_i,\rho_j)\left[\rho_i x_{\rho_i}(\rho_i,\cdot) + x(\rho_i,\cdot) - \Psi_x(x(\rho_i,\cdot))x_{\rho_i}(\rho_i,\cdot)\right] = 0.\end{aligned}$$

Since $[\partial \text{Prob}(\rho_i,\rho_j)/\partial \rho_i]\left[\rho_i x(\rho_i,\cdot) - \Psi(x(\rho_i,\cdot))\right] < 0$, pricing behavior will be more aggressive with potential rivals as the carrier's market share decreases with an increase in the carrier's freight rate. The second-order condition requires

$$\begin{aligned}\frac{\partial^2 \pi^i(\rho_i,\rho_j)}{\partial {\rho_i}^2} &= \frac{\partial^2 \text{Prob}(\rho_i,\rho_j)}{\partial {\rho_i}^2}\left[\rho_i x(\rho_i,\cdot) - \Psi(x(\rho_i,\cdot))\right] \\ &+ 2\frac{\partial \text{Prob}(\rho_i,\rho_j)}{\partial \rho_i}\left[\rho_i x_{\rho_i}(\rho_i,\cdot) + x(\rho_i,\cdot) - \Psi_x(x(\rho_i,\cdot))x_{\rho_i}(\rho_i,\cdot)\right] \\ &+ \text{Prob}(\rho_i,\rho_j)\left[\rho_i x_{\rho_i\rho_i}(\rho_i,\cdot) + 2x_{\rho_i}(\rho_i,\cdot) - \Psi_x(x(\rho_i,\cdot))x_{\rho_i\rho_i}(\rho_i,\cdot)\right. \\ &- \left.\Psi_{xx}(x(\rho_i,\cdot))x_{\rho_i}(\rho_i,\cdot)^2\right] < 0.\end{aligned}$$

Freight rates are strategic complements because

$$\frac{\partial^2 \pi^i(\rho_i,\rho_j)}{\partial \rho_i \partial \rho_j} = \frac{\partial \text{Prob}(\rho_i,\rho_j)}{\partial \rho_j}\left[\rho_i x(\rho_i,\cdot) - \Psi(x(\rho_i,\cdot))\right] > 0.$$

As in the monopoly case, the cross derivative

$$\begin{aligned}
\frac{\partial^2 \pi^i(\rho_i,\rho_j)}{\partial \rho_i \partial \tau} &= \frac{\partial^2 \text{Prob}(\rho_i,\rho_j)}{\partial \rho_i \partial \tau}\left[\rho_i x(\rho_i,\cdot) - \Psi(x(\rho_i,\cdot))\right] \\
&+ \frac{\partial \text{Prob}(\rho_i,\rho_j)}{\partial \tau}\left[\rho_i x_{\rho_i}(\rho_i,\cdot) + x(\rho_i,\cdot) - \Psi_x(x(\rho_i,\cdot))x_{\rho_i}(\rho_i,\cdot)\right] \\
&+ \text{Prob}(\rho_i,\rho_j)\left[\rho_i x_{\rho_i\tau}(\rho_i,\cdot) + x_\tau(\rho_i,\cdot) - \Psi_x(x(\rho_i,\cdot))x_{\rho_i\tau}(\rho_i,\cdot)\right. \\
&- \left.\Psi_{xx}(x(\rho_i,\cdot))x_{\rho_i}(\rho_i,\cdot)x_\tau(\rho_i,\cdot)\right]
\end{aligned}$$

is ambiguous in sign. In an equilibrium with symmetric prices, $\partial\text{Prob}(\rho_i,\rho_j)/\partial\tau = 0$. Note in particular that $[\partial\text{Prob}(\rho_i,\rho_j)/\partial\rho_i x_\tau(\rho_i,\cdot)]\,[\rho_i - \Psi_x(x(\rho_i,\cdot))] > 0$, an effect that is not present in case of a monopoly: a tariff reduction increases exports, and thus the competition for market shares becomes more intense, and this partial effect leads to a decrease in freight rates.

A.2 Independent exporter

As for the interaction with the carrier, this model is closest to the standard models in which an exporting firm takes all costs as given when deciding on foreign sales. In this case, the carrier correctly anticipates how the seller will respond to the tariff and the freight rate. Solving the equivalent maximization problem $\max_x R(x)/(1+\tau) - (c+\gamma+\rho)x$ allows us to determine the anticipated changes in optimal exports x^*. The first-order condition reads $\pi_x = R_x(x^*)/(1+\tau) - (c+\gamma+\rho) = 0$ and the second-order condition $\pi_{xx} = R_{xx}(x^*)/(1+\tau) < 0$ makes this condition also sufficient. The relevant changes in exports in response to tariff and freight rate changes are thus given by

$$\begin{aligned}
x^*_\tau &= -\frac{\pi_{x\tau}}{\pi_{xx}} = \frac{R_x(x^*)}{R_{xx}(x^*)(1+\tau)} < 0, \\
x^*_\rho &= -\frac{\pi_{x\rho}}{\pi_{xx}} = \frac{(1+\tau)}{R_{xx}(x^*)} < 0,
\end{aligned} \tag{A.7}$$

and its cross-derivative is equal to

$$x^*_{\rho\tau} = \frac{R_{xx}(x^*) - \frac{R_x(x^*)R_{xxx}(x^*)}{R_{xx}(x^*)}}{R_{xx}(x^*)^2}. \tag{A.8}$$

Eqs. (A.7) and (A.8) determine the sign of $\pi^c_{\rho\tau}$ in (A.6) together with the features of the transport cost function in the relevant range. Since we cannot rule out that the carrier has spare capacity in the relevant range of x or can build up capacity cheaply such that $\Psi_{xx}(x) < 0$, we find that the effect on the freight rate is ambiguous and depends on the sign of $\pi^c_{\rho\tau}$.

A.3 Mill pricing

In the case of mill pricing, the supplier does not sell directly to customers in the foreign country, but to a number of importers that are active in his own country. In this case, the market is also anonymous and confined to linear pricing, but located in the exporter's country, so the transaction of the supplier is carried out in the exporting country only. The importer acquires inputs or final goods from the independent supplier and arranges transport to the importing country.

Given this background, the supplier will set an export price q that will maximize her profit $\pi^e = (q - c)x$. Since the supplier sells in the exporting country, it has neither to carry any additional cost that may arise in the exporting country nor any transport costs. The pricing behavior of the supplier is given by the first-order condition

$$\pi^e_q = (q^* - c)x_q + x = 0, \tag{A.9}$$

where q^* denotes the profit-maximizing export price. Given q and ρ, the importer profit is given by

$$\pi = R(x) - ((1+\tau)q + \gamma + \rho)\, x, \tag{A.10}$$

Maximization leads to the first-order condition

$$R_x(x^*) - ((1+\tau)q + \gamma + \rho) = 0, \tag{A.11}$$

where x^* denotes the optimal import volume. Both the supplier and the carrier correctly anticipate x^*. The carrier and the exporter act simultaneously, and the marginal changes of imports with the tariff, the export price and the freight rate are respectively given by

$$x^*_\tau = q/\pi_{xx} < 0, x^*_q = (1+\tau)/\pi_{xx} < 0 \text{ and } x^*_\rho = 1/\pi_{xx} < 0,$$

implying

$$x^*_{\rho\rho} = -\frac{\pi_{xxx}}{\pi^3_{xx}}, x^*_{qq} = -\frac{(1+\tau)^2\pi_{xxx}}{\pi^3_{xx}}, x^*_{\rho q} = -\frac{(1+\tau)\pi_{xxx}}{\pi^3_{xx}},$$
$$x^{**}_{\rho\tau} = -\frac{q\pi_{xxx}}{\pi^3_{xx}}, x^*_{\tau\tau} = -\frac{q^2\pi_{xxx}}{\pi^3_{xx}}, x^*_{q\tau} = -\frac{q(1+\tau)\pi_{xxx}}{\pi^3_{xx}}.$$

As a result, we find that the cross derivatives of the carrier's profits and the supplier's profits are given by

$$\pi^c_{\rho\tau} = q(\pi^c_{\rho\rho} - x^*_\rho), \pi^c_{\rho q} = (1+\tau)(\pi^c_{\rho\rho} - x^*_\rho) \tag{A.12}$$

and

$$\pi^e_{q\tau} = \frac{q}{1+\tau}(\pi^e_{qq} - x^*_q), \pi^e_{q\rho} = \frac{1}{1+\tau}(\pi^e_{qq} - x^*_q), \tag{A.13}$$

respectively. Equation (A.13) shows that $\pi^e_{q\rho} > (<) 0$ if $\pi^e_{qq} > (<) x^*_q$, that is, freight rate and export prices are strategic complements (substitutes) for the independent supplier if $\pi^e_{qq} > (<) x^*_q$. Furthermore, we observe that $\pi^c_{\rho q}\pi^e_{\rho q} = (\pi^c_{\rho\rho} - x^*_\rho)(\pi^e_{qq} - x^*_q)$, so that the Jacobian is positive and equal to $\det(J) = x^*_q(\pi^c_{\rho\rho} + \pi^e_{q\rho})$. Defining the two matrices

$$A_1 = \begin{bmatrix} -\pi^c_{\rho\tau} & \pi^c_{\rho q} \\ -\pi^e_{q\tau} & \pi^e_{qq} \end{bmatrix}, A_2 = \begin{bmatrix} \pi^c_{\rho\rho} & -\pi^c_{\rho\tau} \\ \pi^e_{q\rho} & -\pi^e_{q\tau} \end{bmatrix}.$$

allows us to compute the change of the freight rate and the export price with the tariff that are respectively given by

$$\rho^*_\tau = \frac{\det(A_1)}{\det(J)} = -\frac{x^*_q \pi^c_{\rho\tau}}{\det(J)} \tag{A.14}$$

and

$$q^*_\tau = \frac{\det(A_2)}{\det(J)} = -\frac{q x^*_\rho(x^*_q + (q-c)x^*_{qq})}{(1+\tau)\det(J)} < 0. \tag{A.15}$$

respectively, as $x^*_q + (q-c)x^*_{qq} < 0$. Expression (A.14) shows that ρ^*_τ depends on the sign of $\pi^c_{\rho\tau}$.

These results shows that the effect of the tariff rate on the export price is the same as for the independent exporter. The reason is that the supplier anticipates that an increase in the tariff rate will lead to a decrease in her export demand, and she will partially compensate for this decline by lowering the export price. The market has become less profitable, and the supplier is thus able to avoid a too large reduction in her profit by decreasing the export price. The role of the freight rate has not changed: a reduction in freight rates can be a response to a decline in tariffs. Thus, we can show also for this setup that a carrier might reduce the freight rate in order to exploit returns to scale. The interaction between the export price and the freight rate depends on how the freight rate affects the marginal profit of the exporter w.r.t. to the export price. In case of strategic complementarity (substitutability) in the sense of Bulow *et al.* (1985), the export price will co-move (not co-move) with the freight rate.

What will happen if there is more than just one supplier? An additional effect in case of an oligopoly will originate from the strategic interaction among suppliers. But also with strategic interactions of any kind, we do not expect our results to be turned upside down. An increase in the tariff rate reduces the attractiveness of the market for the suppliers, and part of this tariff increase will be carried by suppliers as long as the export price is strictly larger than the marginal production cost. Only in case of perfect competition, the export price will be equal to the marginal production cost and will not change with a change in the tariff or the freight rate.

A.4 Price competition with different qualities

We consider two goods 1 and 2 of potentially different quality. Let $C_i = c_i + \gamma + \rho, i \in \{1, 2\}$. Demand for product i is linear and given by $x_i = A_i - bp_i + \gamma p_j$ where A_i denotes the quality of good i as perceived by consumers, $p_i(p_j)$ denotes the price of good $i(j)$, and $b > \gamma$ holds to ensure that the price effect on own demand is stronger. In case of two independent suppliers of the two qualities, profit maximization is equivalent to maximizing

$$(A_i - bp_i + \gamma p_j)(p_i - (1+\tau)C_i)$$

w.r.t. p_i for each firm. Solving for the equilibrium yields the consumer and export prices

$$p_i^* = \frac{2bA_i + \gamma A_j + b(2b+\gamma)(1+\tau)C_i}{4b^2 - \gamma^2}, q_i^* = \frac{p_i^*}{1+\tau} - \rho,$$

respectively, and differentiation shows that the export price decreases with τ:

$$q_{i_\tau}^* = -\frac{2bA_1 + \gamma A_2}{(4b^2 - \gamma^2)(1+\tau)^2} < 0.$$

Suppose that good 1 is the high-quality good such that $A_1 > A_2$. Then, $q_{1_\tau}^* < q_{2_\tau}^*$ if $(2b - \gamma)(A_1 - A_2) > 0$ which is true. Consequently, we find a "Washington Apples" price effect: the reduction in the high-quality price is larger in absolute terms. If both qualities are sold by a monopolistic multi-product firm that maximizes

$$(A_1 - bp_1 + \gamma p_2)(p_1 - (1+\tau)C_1) + (A_1 - bp_1 + \gamma p_2)(p_2 - (1+\tau)C_2)$$

w.r.t. p_1 and p_2, optimal consumer and export prices are given by

$$p_i^* = \frac{1}{2}\left(\frac{bA_i + \gamma A_j}{b^2 - \gamma^2} + (1+\tau)C_i\right), q_i^* = \frac{p_i^*}{1+\tau} - \rho,$$

and differentiation yields

$$q_{i_\tau}^* = -\frac{bA_i + \gamma A_j}{2(b^2 - \gamma^2)(1+\tau)^2} < 0.$$

Again, $q_{1_\tau}^* < q_{2_\tau}^*$ if $(b - \gamma)(A_1 - A_2) > 0$ which is true. Consequently, we can confirm the "Washington Apples" price effect also for a monopolistic multi-product firm.

A.5 Proof of Proposition 3

The second derivatives and the cross-derivatives are given by $\Pi_{xx} = R_{xx}(x^{**}) - C_{xx}(x^{**}) < 0$, $\Pi_{qq} = -\Delta_{qq}(q^{**}) < 0$, $\Pi_{xq} = -\tau$, $\Pi_{x\rho} = -1$, $\Pi_{q\rho} = 0$, $\Pi_{x\tau} = -q$, $\Pi_{q\tau} = -x$. Thus, the Hessian is equal to $\det(H) = -\left(R_{xx}(x^{**}) - C_{xx}(x^{**})\right)\Delta_{qq}(q^{**}) - \tau^2 > 0$, and we assume that the Hessian is positive, making the first-order conditions sufficient. Writing in matrix form

$$\begin{bmatrix} \Pi_{xx} & -\tau \\ -\tau & \Pi_{qq} \end{bmatrix} \begin{bmatrix} dx^{**} \\ dq^{**} \end{bmatrix} = \begin{bmatrix} 1 \\ 0 \end{bmatrix} d\rho + \begin{bmatrix} q \\ x \end{bmatrix} d\tau$$

allows us to compute the change of the exports and change of the export price with the freight rate and the tariff that are respectively given by

$$x^{**}_\rho = \frac{\Pi_{qq}}{\det(H)} < 0, q^{**}_\rho = \frac{\tau}{\det(H)} > 0, \tag{A.16}$$

$$x^{**}_\tau = \frac{q^{**}\Pi_{qq} + \tau x^{**}}{\det(H)} < 0, q^{**}_\tau = \frac{x^{**}\Pi_{xx} + q^{**}\tau}{\det(H)}. \tag{A.17}$$

$x^{**}_\tau < 0$ because $\Pi_{qq} = -\Delta_{qq}(q)$, $\Delta_q = \tau x^{**}$ and $\xi(q) > 1$. Note that we cannot sign $x^{**}_{\rho\tau}$ in general that determines $\pi^c_{\rho\tau}$ in Proposition 1 together with x^{**}_ρ, x^{**}_τ and $\Psi_{xx}(x^{**})$.

If we employ a more general concealment cost function $\Delta(q, x)$, the first-order conditions (6) change to $R_x(x^{**}) - q^{**}\tau - \rho - C_x(x^{**}) - \Delta_x(q^{**}, x^{**}) = 0, -\tau x^{**} - \Delta_q(q^{**}, x^{**}) = 0$, and the two second-order derivatives now read $\Pi_{xx} = R_{xx}(x^{**}) - C_{xx}(x^{**}) - \Delta_{xx}(q^{**}, x^{**}) < 0$, $\Pi_{xq} = -\tau - \Delta_{xq}(q^{**}, x^{**}) < 0$. The negative sign follows from $\Delta_{xq}(q^{**}, x^{**}) \geq 0$: an increase in imports should not reduce the marginal concealment cost of an import price q, and $\Pi_{xq} < 0$ ensures that the import price increases with the freight rate. The comparative static results do not change as long as the revised Hessian is positive.

Furthermore, tariff valuation is not the only incentive to reduce q: countries also differ in terms of their effective cooperate tax rates, and transfer pricing may help a vertical partnership to reduce its corporate tax burden. Whatever its underpinnings, let us assume that an additional benefit (cost) of lowering q is linear and thus given by $\Lambda(x, q) = \lambda(\tilde{q} - q)x$ for $\lambda > (<)0$. We also assume that $R(x) - C(x)$ can be given by a second-order Taylor approximation such that $\Pi = ax - bx^2/2 - (\tau q + \rho)\, x - C(x) - \Delta(q) + \lambda(\bar{q} - q)x$. The first-order condition w.r.t. x yields

$$x^{**} = \frac{a - \rho - q^{**}\tau + \lambda(\tilde{q} - q^{**})}{\det(H)},$$

and the optimal export price is determined by $-(\tau + \lambda)x^{**} - \Delta_q(q^{**}) = 0$. As $\Pi_{qx} = -(\tau + \lambda)$, a positive Hessian requires $\det(H) = b\Delta_{qq}(q^{**}) - (\tau + \lambda)^2 > 0$. The change of the export price with the tariff is now equal to

$$q_\tau^{**} = \frac{\rho + 2q^{**}(\tau + \lambda) - a - \lambda\tilde{q}}{\det(H)}.$$

For $\lambda > 0$ and even if the tariff rate is zero, that is, $\tau = 0$, $q_\tau^{**} > 0$ if $\rho + 2q^{**}\lambda > a + \lambda\bar{q}$.

A.6 Tariffs and Transport Costs for the Larger Dataset

Table 4 presents the results when we estimate equation (7a) and equation (7b) with the larger dataset that combines the OECD Maritime Transport database and the tariff data from UNCTAD TRAINS.

Table 4: Tariffs and Transport Costs

Equation Transport Cost Measure	(7a) Unit Value	(7a) Ad Valorem	(7b) Unit Value	(7b) Ad Valorem
ln Tariff	0.0439*	0.1492**	1.6248***	1.5390**
	(0.0261)	(0.0687)	(0.6631)	(0.6363)
Importer-Exporter-Product FE	Yes	Yes	No	No
Importer-Time FE	Yes	Yes	No	No
Exporter-Time FE	Yes	Yes	No	No
Product-Time FE	Yes	Yes	No	No
Importer-Product-Time FE	No	No	Yes	Yes
Exporter-Product-Time FE	No	No	Yes	Yes
Adj. R^2	0.6493	0.6161	0.5544	0.5258
N	3,552,425	3,534,992	2,844,359	2,824,004

Notes: Heteroskedasticity-robust clustered standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The number of observations differs between the two transport cost measures due to randomly missing data.

A.7 Different Transport Modes

Tables 5, 6 and 7 give the results comparable to Tables 1, 2 and 3.

Table 5: Tariffs and Transport Costs (Unit Values)

Equation Transport Mode	(7a) Containers	(7a) Tankers	(7a) Bulk	(7b) Containers	(7b) Tankers	(7b) Bulk
ln Tariff	0.035*	0.148***	0.138	1.96***	1.445	3.019***
	(0.019)	(0.038)	(0.124)	(0.673)	(1.592)	(0.671)
Adj. R^2	0.72	0.761	0.773	0.773	0.77	0.809
N	1,957,283	7,145	180,954	1,466,149	4,139	123,646

Notes: Heteroskedasticity-robust clustered standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 6: Export Prices and Tariffs

Equation Transport Mode	(8a) Containers	(8a) Tankers	(8a) Bulk	(8b) Containers	(8b) Tankers	(8b) Bulk
ln Transport Cost	0.039***	0.052	0.109***	0.098***	0.177***	0.247***
	(0.009)	(0.029)	(0.021)	(0.011)	(0.038)	(0.02)
ln Tariff	-0.004	0.397	0.062	0.787***	-0.327	0.064
	(0.022)	(0.271)	(0.122)	(0.199)	(0.733)	(0.24)
Adj. R^2	0.86	0.817	0.869	0.897	0.852	0.914
N	1,746,226	6,859	178,689	1,280,150	3,954	122,175

Notes: Heteroskedasticity-robust clustered standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 7: Trade Volumes and Transport Costs (Unit Values)

Equation	(9a)	(9a)	(9a)	(9b)	(9b)	(9b)
Transport Mode	Containers	Tankers	Bulk	Containers	Tankers	Bulk
ln Trade Volume	-0.021***	-0.062**	-0.05***	-0.068***	-0.134***	-0.109***
	(0.003)	(0.023)	(0.006)	(0.007)	(0.013)	(0.006)
Adj. R^2	0.729	0.762	0.777	0.777	0.792	0.825
N	1,746,227	6,859	178,689	1,280,152	3,954	122,175

Notes: Heteroskedasticity-robust clustered standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

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