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ORIGINAL ARTICLE

Does it matter how we ship the good apples out? On specific tariffs, transport modes, and agricultural export prices

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Abstract

Free-on-board (FOB) export prices for identical products from the same origin often differ across destinations, even when accounting for the trade costs and attributes of the destination country. One explanation for this observed price difference is per-unit trade costs, and the ability of exporters to vary their markups and/or product quality. Using a novel dataset that details trade flows between countries by mode of transport, we estimate the transport mode-specific effect of a per-unit trade cost, specifically specific tariffs, on the FOB export prices of agricultural products. We find an elasticity of specific tariffs to export prices of 1.8%. However, the estimates are heterogeneous across modes of transport. The elasticity of specific tariffs to export prices is 2% for air transport, 5% for road transport, and .3% for sea cargo. Since the observed positive export price effect can reflect product quality differences or markups, we account for the quality element and find that for a given product quality, markups increase with increasing specific tariffs. This form of price discrimination is less pronounced for higher-quality products that are predominantly shipped by air.

KEYWORDS
agricultural trade, export prices, mode of transport, specific tariffs, trade costs

JEL CLASSIFICATION
F41, F42, Q17, Q18

1 | INTRODUCTION

A nascent literature documents systematic export price variation across destinations in the agricultural sector (Curzi & Pacca, 2015; Emlinger & Guimbard, 2021; Fiankor, 2023; Fiankor & Santeramo, 2023). For instance, Swiss cheese can yield free-on-board (FOB) prices—which exclude cost, insurance, and freight costs—ranging from 11 Swiss Francs (CHF) in Peru to 16 CHF in South Korea (Fiankor, 2023). One mechanism that explains this empirical regularity is the presence of per-unit trade costs and the ability of exporters to vary their markups and product quality.[1] When exporters face a per-unit charge in a destination,

[1] Exporters varying the quality of the product the export can take different forms. They can use different packaging for the same product depending on the destination. They can also produce two differentiated varieties within a product category.

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firms may maximize profits by exporting only high-quality versions of their products (Bastos & Silva, 2010; Martin, 2012) because per-unit trade costs make higher-quality varieties cheaper relative to their lower-quality alternatives (Curzi & Pacca, 2015; Emlinger & Guimbard, 2021). This is called the Alchian–Allen effect (Alchian & Allen, 1964). Besides, exporters may arbitrarily vary their markups across destinations due to per-unit charges (Chen & Juvenal, 2022; Fiankor, 2023). One unexplored dimension of this empirical regularity is whether and to what extent the observed spatial price variation is heterogeneous across different modes of transport. Our paper addresses this research gap by asking the following question: considering a per-unit charge, is the variation in FOB export prices across destinations heterogeneous across modes of transport? Where present, is the heterogeneity driven by markups or product quality differentiation?

By its very nature, trade depends on transport, which is also a core part of the post-harvest crop management system. Whether by marine transport, trucks, or trains on land, or air cargo, the entirety of trade in goods goes through the transportation sector. A 1% increase in ocean shipping charges can decrease trade flows by more than 1% (Brancaccio et al., 2020). Transport costs, transit times, product type, and product quality are all key to the transport mode an exporter uses and affect their final pricing decision. Planes are fast, and expensive and tend to carry high-value agri-food products (e.g., fruits, vegetables, and flowers) over longer distances. Over shorter international distances, trucks are convenient for delivering time-sensitive goods. Bulkier agricultural products are delivered by cheaper but more time-consuming ocean cargo. Improvements in transportation technologies and logistics have also reduced product delivery times, increased the competitiveness of distant producers, and enhanced the growth of high-value non-traditional agricultural exports (e.g., cut flowers and fresh vegetable exports from Africa to Europe). However, the existing literature has not analyzed the effects of transport mode-specific trade costs on trade margins for multiple countries. This is because public bilateral trade data are reported as an aggregate across different transport modes. However, as different transport modes have unique features, trade effects at various margins should vary across modes (Wessel, 2019). Taking advantage of a recently released Global Transport Costs Dataset for International Trade (Hoffmeister et al., 2022), which decomposes observed trade flows by mode of transport, we show that this pattern of price variation is heterogeneous across transport modes.

In this paper, we analyze the relationship between specific tariffs—as a measure of per-unit trade costs—and transport mode-specific FOB export prices. The use of specific tariffs has advantages. First, applied researchers usually model and estimate trade costs as multiplicative, but in practice additive trade costs are prevalent (Irarrazabal et al., 2015). Some researchers (Chen & Juvenal, 2022; Fiankor, 2023) resort to bilateral distance to proxy per-unit trade costs. However, as Hummels and Skiba (2004) argue, distance is an imperfect proxy for unit transportation costs. Our choice of specific tariff, by contrast, is a precise measure of per-unit trade costs. Second, high average tariffs generally characterize agricultural and food markets. In most countries, the number of tariffs imposed on agricultural products is higher than those imposed on non-agricultural products. In percentages, the values of tariffs imposed on agriculture tend to also be higher than those imposed on non-agricultural products. Between 1997 and 2015, average tariffs for non-agricultural products decreased from about 9%–5%. In agricultural markets, average tariffs over the same period decreased from 18% to 11% (Niu et al., 2018). The agricultural sector is also special in that the majority of applicable tariffs are per-unit and do not depend on the value of imports.[2] Specific tariffs are administratively simple, as they avoid the challenge of having to value imports. Proponents of specific tariffs argue that ad valorem rates incentivize under-invoicing. However, specific tariffs place a heavier burden on lower-priced items within a given tariff line. In this sense, when used by developed countries they can represent a protectionist measure to limit competition from low-income countries. If specific tariffs are targeted at lower quality or cheaper products then exporters are likely to vary their modes of transport to offset some of the costs. Yet, despite the relevance of specific tariffs in agriculture, their effects on trade patterns remain poorly studied compared with other trade cost measures such as non-tariff barriers (Emlinger & Guimbard, 2021).

Our analysis is based on a dataset of trade values and trade volumes of 123 exporting countries and 98 importing countries across 709 HS6 digit products disaggregated by road, sea, and air transport. With this dataset, we calculate unit values as a proxy for export prices. Our empirical framework exploits variations in specific tariffs as a predictor of transport mode-specific FOB export prices. We estimate a linear model that regresses product and transport mode-specific bilateral FOB export prices on tariffs and bilateral and country-product-transport mode fixed effects. Consistent with the existing literature (Emlinger & Guimbard, 2021), we estimate an elasticity of FOB export price to specific tariffs of 1.8%. More importantly, our findings reveal heterogeneity in the estimates across modes of transport. Specifically, we estimate an elasticity of FOB export price to specific tariffs of 2% for air cargo, 5% for

[2] There are other less popular forms of tariff administration such as compound tariffs, tariff rate quotas, and retaliatory tariffs.

road, and .2% for sea freight. We explore another source of heterogeneity and show that conditional on product quality, markups covary positively with specific tariffs. From this perspective, our results are consistent with recent trade literature (Chen & Juvenal, 2022) and are novel in showing that this pattern exists across modes of transport. We explore alternative sources of heterogeneity and show that the magnitude of the price increases is lower in developed countries.

Our work contributes to the literature in two ways. First, the paper adds to a nascent stream of research that assesses the heterogeneity of the elasticity of per-unit trade costs to FOB export prices across product quality and markups (Chen & Juvenal, 2022), consumer taste (Haase et al., 2022), firm size (Fiankor, 2023) and the development level of the exporting country (Emlinger & Guimbard, 2021; Fiankor & Santeramo, 2023). These analyses extend the empirical trade literature that tests the Alchian–Allen effect. For example, Curzi and Pacca (2015) report a positive relationship between specific tariffs, export prices, and quality in the European food sector. Emlinger and Guimbard (2021) confirm this finding for all agricultural products and bilateral trade flows but show that the effects are more pronounced for developed country exporters. Fiankor and Santeramo (2023) replicate and extend the findings in Emlinger and Guimbard (2021) and find that the positive effect of per-unit trade costs on export prices may depend more on the price levels of the traded goods. On product-specific findings, Miljkovic and Gómez (2019) and Miljkovic et al. (2019) examine the relative demand for quality-differentiated coffee varieties exported globally and confirm that a common per-unit charge increases the quality of coffee demanded. We confirm and extend these findings along a previously unexplored dimension, that is, the mode of transport.

Second, variable markups, product quality, or a combination of both mechanisms may explain the positive specific tariff elasticity of export prices. Existing analyses embed both mechanisms and do not attempt to disentangle them (Curzi & Pacca, 2015; Emlinger & Guimbard, 2021; Fiankor & Santeramo, 2023). Our second contribution is the decomposition of the positive effect of per-unit trade costs on export prices into quality and markups. Chen and Juvenal (2022) show that conditional on wine quality, Argentine wine-producing firms price discriminate and set higher markups and, thus, higher prices in more distant countries. Fiankor (2023) finds that if distance doubles, the average Swiss agri-food exporting firm increases its FOB export price by 2.3%. Nevertheless, this form of price discrimination is less pronounced for higher-quality products. Drawing on Italian firm-level customs data, Haase et al. (2022) show that export prices rise with distance, but higher-grade products attenuate these impacts on markups. Our work shows that conditional on product quality, markups covary positively with specific tariffs. From this perspective, our results are consistent with recent trade literature (Chen & Juvenal, 2022; Fiankor, 2023). However, our results are novel in showing that this pattern exists across modes of transport.

Testing the validity of the law of one price (LOP) is a popular question in agricultural economics (Gobillon & Wolff, 2016). Whenever prices differ between two separate markets, spatial arbitrage is supposed to remove this difference (Fackler & Goodwin, 2001). Whether exporters sell differentiated or homogeneous products and charge the same or different prices across partners located in various destinations is key to understanding deviations from the LOP (Fontaine et al., 2020). Our results have implications for future studies aimed at testing the LOP, as we show that the transportation mode represents an additional source of variation in the FOB price. Furthermore, even as CO_2 generated by transport is a small fraction (3%–4%) of overall CO_2 emissions, transport-related emissions are a third of total emissions (production and transport) created by traded goods (Cristea et al., 2013). Our findings when considered vis-a-vis the emission intensity of the different modes of transport will help policy efforts along the trade, transportation, and environment nexus.

The rest of the paper proceeds as follows. Section 2 presents our empirical strategy. We present and discuss the data and some stylized facts in Section 3. Section 4 presents and discusses the results. Our conclusions are presented in Section 5.

2 | EMPIRICAL APPROACH

2.1 | The effect of specific tariffs on import values

Given the novelty of the GTCDIT database, we conduct an initial exploratory analysis to assess the quality of our dataset. We confirm the quality of the dataset within what is considered one of the most successful empirical relationships in international economics: a structural gravity framework. We regress transport mode-specific bilateral trade values on country-product-transport mode fixed effects and bilateral trade costs using the Poisson pseudo-maximum likelihood estimator as follows:

$$\begin{aligned} X_{ijkm} = \exp\Big[\beta_0 &+ \beta_1 \log \text{Specific tariff}_{ijk} \\ &+ \beta_2 \log \text{Ad valorem tariff}_{ijk} \\ &+ \mathbf{b}'\mathbf{w}_{ij} + \phi_{ikm} + \phi_{jkm}\Big] + \varepsilon_{ijkm}, \end{aligned} \tag{1}$$

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where X_{ijkm} is export values from country i to importing country j of HS6 digit product k via transport mode m (i.e., air, road, or sea). β_1 and β_2 capture the effects of specific and ad valorem tariffs on export values which are based on the power of tariffs (i.e., $1 + t$, where t is the tariff measure). The power of the tariff is an appealing metric because for cases in which the metric is the tariff, rather than the power of the tariff, log-transformed tariff variables would be indeterminate if protection is zero (Bouët et al., 2008). w_{ij} is a vector of bilateral varying gravity variables including colonial ties, contiguity, common language, and membership in a free trade area. The variables in w_{ij} are from two sources. Data on free trade agreements are from Egger and Larch (2008). All remaining variables are from the Centre d'Etudes Prospectives et d'Informations Internationales (CEPII). ϕ_{ikm} and ϕ_{jkm} capture the theoretical multilateral resistance terms (Anderson & Van Wincoop, 2003) and control for all country-product and transport mode-specific effects. Here, we estimate a less stringent model specification without bilateral fixed effects. This allows us to test how coefficients on the traditional gravity variables behave in a sub-sample of different transport modes enabling us to confirm various empirical regularities in our trade dataset.

2.2 | The effect of specific tariffs on FOB unit values

Following Emlinger and Guimbard (2021), we estimate a linear model of the following form using ordinary least squares:

$$\log UV_{ijkm} = \beta_0 + \beta_1 \log \text{Specific tariff}_{ijk} + \beta_2 \log \text{Ad valorem tariff}_{ijk} + \phi_{ij} + \phi_{ikm} + \phi_{jkm} + \varepsilon_{ijkm} \quad (2)$$

where our dependent variable is the FOB export prices (unit values)—calculated as the ratio of export values in USD to export quantities in tons—of exports from country i to importing country j of HS6 digit agricultural product k via transport mode m (i.e., air, road, or sea). Since unit values are noisy, especially when either the value or quantity of exports are misreported, we drop unit values below and above the 1st and 99th percentiles of the unit value distribution. In Equation (2), β_1 captures the average effect of specific tariffs on export prices across all transport modes. We also control for ad valorem tariffs whose effect is captured by β_2. ϕ_{ij} are bilateral fixed effects. ϕ_{ikm} and ϕ_{jkm} are country-product-mode triple fixed effects, which control for demand and supply shocks within countries and any global product- and mode-specific shocks. Other variables affect FOB export prices, which, at first glance, appear missing from our specification. For instance, in larger countries, competition is fiercer, as they are more likely to host many more firms. In turn, prices and markups are lower (Melitz & Ottaviano, 2008). In high-income countries, consumers may have a higher willingness to pay for quality, which means that export prices may be higher (Bastos & Silva, 2010). Prices charged by exporting firms may also be higher in more remote destinations, and depend on the average prices in the destination country. By including ϕ_{jkm} in our model specifications, we account for all these destination-specific effects. Finally, we allow for unobserved trade costs via the idiosyncratic error term ε_{ijkm} which we cluster at the country-pair-product level. Equation (2) is routinely used to quantify the effects of trade costs on different trade margins. However, we do not know how these effects differ by mode of transport. To unravel transport mode-specific effects, we estimate Equation (3):

$$\begin{aligned} \log \text{UV}_{\text{ijkm}} = \beta_0 &+ \beta_1^a \log \text{Specific tariff}_{\text{ijk}} \times \text{Air} \\ &+ \beta_1^r \log \text{Specific tariff}_{\text{ijk}} \times \text{Road} \\ &+ \beta_1^s \log \text{Specific tariff}_{\text{ijk}} \times \text{Sea} \\ &+ \beta_2 \log \text{Ad valorem tariff}_{\text{ijk}} \\ &+ \phi_{\text{ij}} + \phi_{\text{ikm}} + \phi_{\text{jkm}} + \varepsilon_{\text{ijkm}} \end{aligned} \quad (3)$$

where the variables remain as defined in Equation (1). The β_1^a, β_1^r, and β_1^s coefficients capture the effects of specific tariffs on the transport mode-specific bilateral trade values that are of interest to us.[3] Consistent with theory, we expect that $\beta_1 > 0$.

The β_1 coefficients we estimate in Equations (2) and (3) reflect product quality differences, markups, or a combination of both mechanisms. Firms could be charging higher prices because they are selling higher quality products in destinations with specific tariffs, or they could be only varying their markups. By focusing on the agricultural sector, which is a rather homogeneous sector, one can argue that we disregard the quality channel and ascribe all the variation in unit values across destinations that impose higher per-unit tariffs to markups. However, as consumers become less sensitive to price and more sensitive to quality, firms in the agri-food industry have adopted vertical product differentiation strategies (Grunert, 2005). Thus, we test the existence of product quality in our data, control for its effect on export prices, and isolate a pure markup

[3] We consider a robustness of Equation (2) estimated separately by transport mode in Appendix Table A6.

component using the following regression:

$$\log \text{UV}_{ijkm} = \beta_0 + \beta_1 \log \text{Specific tariff}_{ijk} + \beta_2 \log \text{Ad valorem tariff}_{ijk} + \beta_3 \text{Quality}_{ijk} + \beta_4 \log \text{Specific tariff}_{ijk} \times \text{Quality}_{ijk} + \phi_{ij} + \phi_{ikm} + \phi_{jkm} + \varepsilon_{ijkm} \quad (4)$$

where the variables remain as defined in Equations (1) and (2). β_3 captures the effect of product quality on FOB export prices, and β_4 tests how product quality moderates the effects of specific tariffs on mode of transport-specific export prices.

Critical to this part of the analysis is how we measure unobservable "product quality". The main challenge in the empirical analysis of the Alchian—Allen effect has been the lack of precise definitions of product quality (Emlinger & Lamani, 2020). Studies that focus on a single product have managed to overcome this limitation using some observable product features to proxy quality. Miljkovic and Gómez (2019) and Miljkovic et al. (2019) examine the relative demand for quality-differentiated coffee varieties—Colombian Arabica (high-quality), Brazilian Arabica (medium-quality), and Brazilian Robusta (low-quality). Chen and Juvenal (2022) use expert ratings for wines as a proxy for quality. For cognac, Emlinger and Lamani (2020) use the minimum time in oak of the youngest eau-de-vie used in creating the blend. Given our multi-product focus, our approach follows Khandelwal et al. (2013) and recovers quality directly from observed trade data.[4] See Appendix A1 for a detailed description of the quality estimation procedure.

3 | DATA

Our analyses combine bilateral trade data—decomposed by mode of transport—and data on tariffs that are either measured as per-unit or ad valorem. In this section, we describe the various datasets, and their sources and provide stylized facts where relevant.

3.1 | Bilateral trade data by mode of transport

We retrieve our trade data from the recently launched Global Transport Costs Dataset for International Trade (GTCDIT). The dataset is based on the joint efforts of the United Nations Conference for Trade and Development (UNCTAD) and the World Bank to develop a novel information source on transport costs and networks for the shipment of commodities between countries (Hoffmeister et al., 2022). The GTCDIT contains bilateral trade values in USD and volumes in tons by HS6 commodity broken down by mode of transport for 2016.[5] We focus our analysis on agricultural products, which we define following the World Trade Organization (WTO) classification[6] because specific tariffs tend to be more heavily used in regulating agricultural products. The total number of observations is 858,147 across four transport modes: air (263,652), railway (17,224), road (303,998), and sea (384,584). The data on rail connections are, however, incomplete with 17,057 out of the 17,224 railway observations having no data on either trade volumes or values. As a result, the rail connection drops from the sample when we calculate unit values. To ensure consistency, we drop the rail connection from the analyses. Our final dataset includes 194 exporters, 100 importers, and 686 HS6 digit products and three modes of transport: air, sea, and road. We present a list of importing and exporting countries in Table A1 in the Appendix.

Figure 1a–c display maps that show the share of exports per country transported via various transport modes. Most exports are transported by sea, whereas air cargo is still a rare mode of transport for agricultural products. Road transport is predominant in Europe, especially within the European Union. In Figure 1d, we plot a graph of unit values–net of country and product fixed effects–by mode of transport. Unit values are highest for products shipped by air relative to products shipped by road and sea freight, with the latter two only differing marginally.

[4] Although this method was originally applied at the firm-product-country-year level, subsequent applications have also been done at the product-country-year level, see for example, Curzi and Pacca (2015), Fiankor et al. (2021). The limitation, however, is that different producers or firms may produce different qualities. The lack of farm/firm-level trade data implies that our quality estimates reflect the average quality of exports from a country. The intuition behind Khandelwal et al. (2013) is simple: conditional on prices, varieties with higher quantities (market shares) are assigned higher quality. For instance, suppose bananas from Ecuador and Colombia are equally priced, but Colombia's market share in destination market *j* is 20% and Ecuador's is 10%, the quality estimate for Colombia will be higher. If bananas from Colombia were more expensive, then we would need to control for the price difference and this would reduce the quality estimate for Colombia.

[5] The dataset currently entails only data for 2016. For more information, see https://unctad.org/news/why-and-how-measure-international-transport-costs.

[6] These include HS Chapters 1–24 less fish and fish product (HS Chapter 3), HS 290543, HS 290544, HS3301, HS3501–3505, HS380910, HS382360, HS4101–4103, HS 4301, HS5001–5003, HS5101–5103, HS5201–5203, HS5301 and HS5302. See https://www.wto.org/english/docs_e/legal_e/14-ag_02_e.htm.

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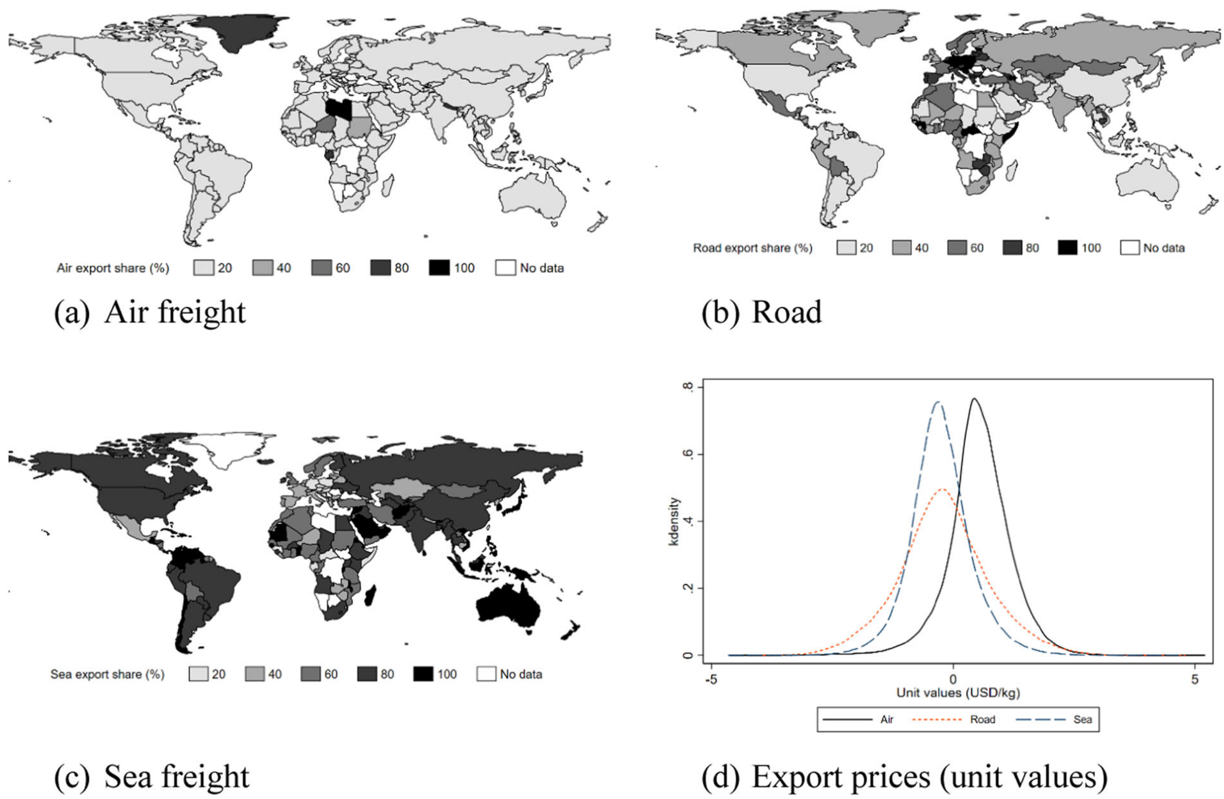


FIGURE 1 Export shares and prices by mode of transport.
Source: GTCDIT dataset (Hoffmeister et al., 2022).

3.2 | Tariff data

Our tariff data come from the MAcMap-HS6 database maintained by the CEPII and the International Trade Center (Guimbard et al., 2012). This data set provides bilateral measurements of applied tariff duties at the HS6 digit product level expressed either as ad valorem or per-unit in current USD/ton.[7] Although Article 4 of the Agreement on Agriculture required member states to convert certain market access barriers in agriculture into ordinary customs duties (WTO, 2022), it did not specify whether these duties should be ad valorem or specific. This left a broad scope for specific tariffs. Specific tariffs are predominantly used by higher-income countries (Figure 2a); some of them such as Switzerland, exclusively use specific tariffs (Figure 2b). We provide a similar graph for ad valorem tariffs in Figure A1 of the Appendix, which shows a pattern that contrasts that of Figure 2.

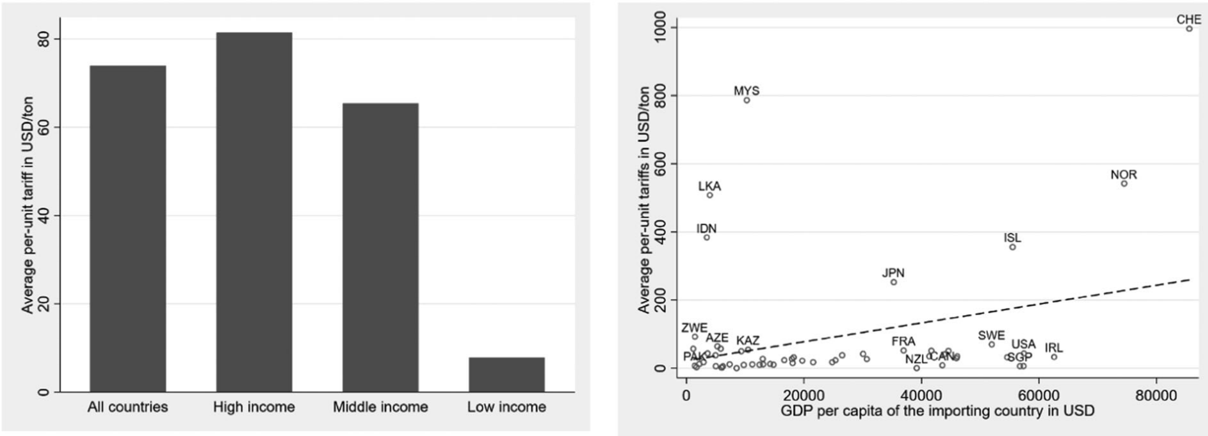
These very high specific tariffs in high-income countries all but offset the benefits that developing countries derive from the non-reciprocal tariff preferences that they are granted in other nonagricultural sectors (Chowdhury, 2012; Guimbard et al., 2012). As they are expressed in per-unit terms rather than as a share of value, the effective protection provided by a given specific tariff varies with price levels. Since low-income countries tend to have lower export prices compared to high-income countries, it means that when both sets of exporters face the same level of specific tariff, exporters in low-income countries face higher ad valorem equivalents (AVEs). Thus, specific tariffs might be most-favored-nation on paper but discriminatory in nature (Chowdhury, 2012).

We provide summary statistics on tariffs and trade outcomes for the three modes of transport in Table 1 (see also Table A2 for summary statistics on all variables used in the empirical analysis). We see that average FOB unit values differ by mode of transport, confirming the pattern in Figure 1d, as do the average tariffs, trade volumes, and trade values. Consistent with Hummels (2007), sea freight forms the majority of trade in volumes but forms a much smaller share when measured in values and unit values.

4 | RESULTS

We present and discuss the results of our empirical analysis in this section. First, we present the trade value effects of

[7] For cases in which we observe a compound or mixed tariff, our dataset records for the same importer-exporter-product combination, one value for the per-unit component and another value for the ad valorem tariff component.



(a) Specific tariffs and income classes (b) Specific tariffs and per capita GDP

FIGURE 2 Distribution of specific tariffs by income classifications.

Source: MACMAP (Guimbard et al., 2012) and World Bank WDI data.

TABLE 1 Structure of shipments by mode of transport (sample averages).

Mode	Specific tariff (USD/ton)	Unit value (USD/kg)	Export value (USD)	Export volume (kg)	Observations
Air	81.98	11.26	220,337	112,360	254,501
Road	64.23	5.85	1,289,907	3,068,023	250,313
Sea	75.02	4.46	1,390,505	2,745,987	336,003

specific tariffs in Section 4.1 to confirm the quality of our dataset. We begin the discussion of our main findings in Section 4.2. We then isolate the various mechanisms driving our results in Section 4.3. Finally, we check our main findings for endogeneity in Section 4.4.

4.1 | Stylized facts—confirming traditional findings with new data

We present the results of estimating Equation (1) in Table 2.[8] The findings confirm the standard predictions of the trade literature (Head & Mayer, 2014). Trade is reduced by distance and tariffs and enhanced by sharing a common language, a border, a colonial relationship, or a free trade area. In order of magnitude, we find that the trade-reducing effect of distance is largest for road transport relative to air and sea transport. This finding is consistent with those reported by Wessel (2019) and validates our dataset. Nevertheless, given that Wessel (2019) only considers trade between 20 EU countries, our results for all bilateral trade pairs are novel. If we include bilateral fixed effects (ϕ_{ij}) instead of the country-pair varying variables (i.e., $\mathbf{b'w}_{ij}$ in Equation 1), our main findings remain largely the same in direction and statistical significance, with the magnitudes only marginally different (see Table A3 of the appendix). Further, given that trade volumes (tonnage) may determine mode choice more than trade values, we also run a similar regression but with the dependent variable measured as trade volumes in tonnes. Here again, our findings remain largely the same, although with minor differences: the magnitudes of the estimated effects are larger, which means specific tariffs reduce trade volumes relatively more than they do for trade values (see also Emlinger

[8] Although the PPML estimator's log-linear objective function allows us to specify the gravity equation in its multiplicative form without log-transforming the dependent variable (Silva & Tenreyro, 2006), we estimate the model on the sample of non-zero trade observations for two reasons. First, squaring the transport mode and product-specific bilateral trade data set generates over 40 million observations (i.e., 194 exporters × 100 importers × 686 HS6 digit products × 3 years). Second, by squaring the trade matrix we are likely to include impossible country-pair mode choices, e.g., landlocked countries using sea freight. We avoid such possibilities if we use non-zero reported trade values. More generally, we note that the presence of zero-valued dependent variables can seriously bias econometric estimates, regardless of whether the zeros are included or excluded. However, the widely-used gravity model is frequently estimated on samples that include large fractions of zeros. As Martin and Pham (2020) note, omitting observations with zero-valued dependent variables or including them without modification results in potentially other serious biases. Nevertheless, in our case, there are often very few differences between estimates from the PPML estimator and its truncated version (Martin & Pham, 2020).

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TABLE 2 PPML estimation results for the effect of specific tariffs on export values by mode of transport.

	Export values			
	Aggregate	Air	Road	Sea
Dependent variable	(1)	(2)	(3)	(4)
log Specific tariff$_{ijk}$	−.080***	−.058***	−.241***	−.057***
	(.018)	(.022)	(.022)	(.023)
log Ad valorem tariff$_{ijk}$	−2.338***	−3.704***	−6.578***	−2.125***
	(.527)	(.411)	(.634)	(.549)
log Distance$_{ij}$	−.658***	−.357***	−.816***	−.656***
	(.027)	(.036)	(.047)	(.032)
Colony$_{ij}$	.227***	.089	.117	.258***
	(.059)	(.073)	(.112)	(.078)
Border$_{ij}$	.583***	−.044	.710***	−.061
	(.057)	(.112)	(.073)	(.105)
Language$_{ij}$	.274***	.233***	.475***	.122**
	(.048)	(.066)	(.077)	(.058)
FTA$_{ij}$	.147**	.232***	.086	.290***
	(.059)	(.087)	(.104)	(.075)
Importer-product-(transport mode) FE	Yes	Yes	Yes	Yes
Exporter-product-(transport mode) FE	Yes	Yes	Yes	Yes
Importer-exporter FE	No	No	No	No
Observations	793,667	241,438	236,926	315,303

Notes: *p* values in parentheses. ***, **, * denote significance at 1%, 5% and 10% respectively. Intercepts included but not reported. All models are estimated using the Poisson pseudo-maximum likelihood (PPML) estimator. The dependent variable is the export values from country *i* to country *j* of product *k* via transport mode *m*.

& Guimbard, 2021), and the specific tariffs have no statistically significant effect on trade volumes via air (see Table A4 of the Appendix).

4.2 | The effect of specific tariffs on transport mode-specific export unit values

The estimated coefficient of specific tariffs on export prices is .018 in column (1) of Table 3. A 10% increase in per-unit tariffs is associated with a 0.2% increase in FOB export prices. The positive impact of specific tariffs on export prices means that exporters charge higher prices in destinations with higher per-unit duties. Our effect size is consistent with those of Emlinger and Guimbard (2021) and Fiankor and Santeramo (2023), who estimate an effect of .01 using a country-product panel dataset. The novelty of our contribution is to assess whether and to what extent the aggregate effect of per-unit tariffs in column (1) differs by mode of transport. We report these transport mode-specific estimates in column (2) of Table 3. Conditional on exporting the same product, the positive effect of specific tariffs on FOB export prices is decreasing in economic magnitude for road, air, and sea freight (i.e., $\beta_2^r > \beta_1^a > \beta_3^s$).

TABLE 3 OLS estimation results for the effect of specific tariffs on export prices by mode of transport.

	FOB unit values	
Dependent variable (log)	(1)	(2)
log Specific tariff$_{ijk}$	.018***	
	(.002)	
log Specific tariff$_{ijk}$ × Air		.019***
		(.002)
log Specific tariff$_{ijk}$ × Road		.047***
		(.004)
log Specific tariff$_{ijk}$ × Sea		.003*
		(.002)
log Ad valorem tariff$_{ijk}$	.153***	.155***
	(.038)	(.038)
Importer-product-transport mode FE	Yes	Yes
Exporter-product-transport mode FE	Yes	Yes
Importer-exporter FE	Yes	Yes
Observations	775,896	775,896
Adj. R^2	.681	.681

Notes: *p* values in parentheses. ***, **, * denote significance at 1%, 5% and 10% respectively. Intercepts included but not reported. All models are estimated using ordinary least squares (OLS). The dependent variable is the log of FOB unit values of exports from country *i* to country *j* of product *k* via transport mode *m*.

TABLE 4 OLS estimation results for the effect of specific tariffs on export prices by mode of transport: Heterogeneity across income classes.

GDP per capita of	Destination country		Origin country	
	(1)	(2)	(3)	(4)
log Specific tariff$_{ijk}$	.092***		.009	
	(.021)		(.007)	
log Specific tariff$_{ijk}$ × log GDP per capita	−.007***		.001	
	(.002)		(.001)	
log Specific tariff$_{ijk}$ × Air		.065**		.021**
		(.029)		(.009)
log Specific tariff$_{ijk}$ × Road		.093**		−.022
		(.041)		(.019)
log Specific tariff$_{ijk}$ × Sea		.044*		.001
		(.023)		(.007)
log Specific tariff$_{ijk}$ × Air × log GDP per capita		−.004		−.000
		(.003)		(.001)
log Specific tariff$_{ijk}$ × Road × log GDP per capita		−.005		.007***
		(.004)		(.002)
log Specific tariff$_{ijk}$ × Sea × log GDP per capita		−.004*		.000
		(.002)		(.001)
log Ad valorem tariff$_{ijk}$	.157***	.157***	.153***	.157***
	(.038)	(.038)	(.038)	(.038)
Importer-product-transport mode FE	Yes	Yes	Yes	Yes
Exporter-product-transport mode FE	Yes	Yes	Yes	Yes
Importer-exporter FE	Yes	Yes	Yes	Yes
Observations	775896	775896	775531	775531
Adj. R^2	.681	.681	.681	.681

Notes: *p* values in parentheses. ***, **, * denote significance at 1%, 5% and 10% respectively. Intercepts included but not reported. All models are estimated using ordinary least squares (OLS). The dependent variable is the log of FOB unit values of exports from country *i* to country *j* of product *k* via transport mode *m*.

4.2.1 | Heterogeneous effects

In this section, we test the heterogeneity of our main findings along three dimensions: (i) the level of development of the importing country, (ii) the level of development of the exporting country, and (iii) across low- and high-priced commodities.

Given that there is a clear developed-developing country divide in the use of specific tariffs (Figure 2), we check whether exporters further vary their FOB export prices depending on the income level of the destination country. The results are presented in Table 4. In column (1) we find that the effect of specific tariffs on FOB export prices is lower in higher-income or more developed countries. We would expect per capita GDP—that is, our measure of income—to have a positive effect on export prices which may arise from the fact that in higher-income countries, consumers have a higher willingness to pay (Bastos & Silva, 2010). However, these high-income countries are also larger—measured here in terms of their GDPs—and thus more likely to host many more firms. Therefore, competition is tougher, which means prices and markups are lower (Melitz & Ottaviano, 2008). In column (2), we find that this particular effect is not moderated by the mode of transport used. Regardless of mode choice, FOB export prices are lower in richer countries.

Specific tariffs are more restrictive than their ad valorem counterparts when targeted against cheap exports, which are often from developing countries. Emlinger and Guimbard (2021) provide suggestive evidence that the Alchian–Allen effect may be heterogeneous across the income level of the exporter as well. Fiankor and Santeramo (2023) caution that this interpretation may not be straightforward, as the effects only exist for high-priced products. We also observe descriptive evidence in Figure 1 that marine transport is very common among developing countries. This could explain, in part, the lower magnitude of sea freight that we estimate in Table 3. To obtain further insights into this dimension of our dataset, we introduce an interaction between the GDP per capita of the exporting

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TABLE 5 OLS estimation results for the effect of specific tariffs on export prices by mode of transport: Heterogeneity across high- and low-priced products.

	Low-priced products		High-priced products	
	(1)	(2)	(3)	(4)
log Specific tariff$_{ijk}$	.021***		.007	
	(.005)		(.005)	
log Specific tariff$_{ijk}$ × Air		.030*		.007
		(.016)		(.006)
log Specific tariff$_{ijk}$ × Road		.021***		.005
		(.007)		(.011)
log Specific tariff$_{ijk}$ × Sea		.020***		.013
		(.007)		(.023)
log Ad valorem tariff$_{ijk}$	−.332***	−.334***	−.133	−.133
	(.106)	(.106)	(.108)	(.108)
Importer-product-transport mode FE	Yes	Yes	Yes	Yes
Exporter-product-transport mode FE	Yes	Yes	Yes	Yes
Importer-exporter FE	Yes	Yes	Yes	Yes
Observations	54889	54889	44467	44467
Adj. R^2	.567	.567	.617	.617

Notes: *p* values in parentheses. ***, **, * denote significance at 1%, 5% and 10% respectively. Intercepts included but not reported. All models are estimated using ordinary least squares (OLS). The dependent variable is the log of FOB unit values of exports from country *i* to country *j* of product *k* via transport mode *m*. Low-priced products are those with unit values in the lower decile of the unit value distribution. High-priced products are those with unit values in the upper decile of the unit value distribution.

country and our variable of interest. We present the results in columns (3) and (4) of Table 4. Our findings show that the FOB export price variation induced by specific tariffs does not depend on the level of development of the exporting country.

The additive nature of per-unit duties makes their protection higher for low-priced products. In a last set of heterogeneity analyses, we test whether our main findings depend on where the product falls within the unit value distribution, that is, high- or low-priced commodities. We present the results in Table 5. In columns (1) and (2), we restrict our sample to observations with unit values in the lower decile of the unit value distribution (i.e., $UV_{ijkm} \leq 1$ USD/kg). These products have very low prices, which implies that they may be of lower quality. Specific tariffs increase the FOB export prices of these products across all modes of transport. In contrast, ad valorem tariffs reduce the FOB export prices of lower-priced products. In columns (3) and (4), we focus on high-priced products whose prices fall in the upper decile of the unit value distribution (i.e., $UV_{ijkm} \geq 14.7$ USD/kg). These products have higher prices, implying that they may be of higher quality. Here, tariffs do not have a statistically significant effect on FOB export prices. These results imply that the spatial price variation induced by per-unit trade costs is higher for products of lower quality. In the next section, we describe the results of a more explicit test of this conclusion.

4.3 | Isolating product quality and markup mechanisms

There are two potential explanations for the positive effect of specific tariffs on export prices we find—variable markups and product quality differences. First, exporters could be charging higher markups and thus higher prices in response to the increased trade costs induced by specific tariffs. Thus, conditional on shipping product *k*, exporters charge higher markups on products they ship via road compared to air and sea freight. Second, if we consider unit values as a proxy for product quality (e.g., Bojnec & Fertö, 2017; Emlinger & Guimbard, 2021), we can interpret the positive effect as evidence of an Alchian and Allen (1964) type composition effect (Hummels & Skiba, 2004) or a selection of high-quality producing firms into markets with per-unit tariffs (Bastos & Silva, 2010). This will, however, mean that, when all transport modes are used, higher-quality products are shipped in order of importance by road, air, and sea freight. This finding remains the same when we drop intra-EU trade flows, in which sea freight can most easily be substituted for inland transportation (Table A5). However, this quality-related interpretation is counterintuitive as we would expect higher-quality products to be exported by air. This is probably because the β_1 coefficient we estimate combines both quality and markup elements. Here, we attempt to shed light on the two mechanisms driving the results in Table 3 by disentangling

TABLE 6 OLS estimation results for the effect specific tariffs on export prices by mode of transport: Controlling for product quality.

	FOB unit values		
***Dependent variable* (log)**	**(1)**	**(2)**	**(3)**
log Specific tariff$_{ijk}$	.013***	.013***	
	(.002)	(.002)	
Quality$_{ijk}$	.047***	.050***	.050***
	(.002)	(.002)	(.002)
log Specific tariff$_{ijk}$ × Quality$_{ijk}$		−.005***	
		(.001)	
log Specific tariff$_{ijk}$ × Air			.017***
			(.002)
log Specific tariff$_{ijk}$ × Road			.039***
			(.005)
log Specific tariff$_{ijk}$ × Sea			.002
			(.002)
log Specific tariff$_{ijk}$ × Air × Quality$_{ijk}$			−.009***
			(.002)
log Specific tariff$_{ijk}$ × Road × Quality$_{ijk}$			.029***
			(.002)
log Specific tariff$_{ijk}$ × Sea × Quality$_{ijk}$			−.027***
			(.001)
log Ad valorem tariff$_{ijk}$	.224***	.225***	.229***
	(.045)	(.045)	(.045)
Importer-product-transport mode FE	Yes	Yes	Yes
Exporter-product-transport mode FE	Yes	Yes	Yes
Importer-exporter FE	Yes	Yes	Yes
Observations	469,095	469,095	469,095
Adj. R^2	.710	.711	.712

Notes: *p* values in parentheses. ***, **, * denote significance at 1%, 5% and 10% respectively. Intercepts included but not reported. All models are estimated using ordinary least squares (OLS). The dependent variable is the log of FOB unit values of exports from country *i* to country *j* of product *k* via transport mode *m*. Product quality is estimated following Khandelwal et al. (2013).

quality and markup mechanisms. We present the results in Table 6.

In the first step, we introduce quality as an extra control variable in column (1) and find that higher-quality products sell for higher prices. Given that we now control for product quality along with a host of fixed effects, we can ascribe the remaining variation in export prices to markups. In column (2), we interact our quality measure with specific tariffs and estimate a negative and statistically significant effect. This implies that in the presence of specific tariffs, FOB export prices—which now capture markups—are higher but relatively lower for products of a higher quality. In column (3), we confirm this prediction for the different modes of transport. The observed price variation is less for higher-quality products shipped by air. This finding clarifies two of our baseline findings—the fact that the positive effects of specific tariffs on FOB export prices are stronger for low-priced products (Table 5) and for products shipped by road (Table 3).

Thus, our findings show that conditional on product quality, exporters charge higher markups in destinations with higher per-unit trade costs. This finding is consistent with recent firm-level evidence on Colombia (Chen & Juvenal, 2022) and Switzerland (Fiankor, 2023). However, even if exporters price discriminate, they discriminate less for high-value products, which are often shipped by air. Markups are highest for products shipped by road.

4.4 | Instrumenting for trade policy changes

We do not interpret our estimate of the effect of specific tariffs on export prices as causal, as we acknowledge that there may be endogeneity concerns in our cross-sectional setup given that countries tend to protect their domestic sectors more when they face competition from cheaper imports. To control for the potential simultaneity of the

TABLE 7 IV estimation results for the effect of specific tariffs on export prices by mode of transport.

	FOB unit values	
Dependent variable **(log)**	**(1)**	**(2)**
log Specific tariff$_{ijk,2007}$	.023***	
	(.002)	
log Specific tariff$_{ijk,2007}$ × Air		.022***
		(.003)
log Specific tariff$_{ijk,2007}$ × Road		.060***
		(.005)
log Specific tariff$_{ijk,2007}$ × Sea		.006**
		(.002)
log Ad valorem tariff$_{ijk,2007}$	.398***	.407***
	(.093)	(.093)
Importer-product-transport mode FE	Yes	Yes
Exporter-product-transport mode FE	Yes	Yes
Importer-exporter FE	Yes	Yes
K–P Wald F-stat	454.287	454.440
A–R Wald test (*p*-value)	.000	.000
Observations	651460	651460

Notes: *p* values in parentheses. ***, **, * denote significance at 1%, 5% and 10% respectively. Intercepts included but not reported. Both models are estimated using two-stage least squares (2SLS). The dependent variable is the log of FOB unit values of exports from country *i* to country *j* of product *k* via transport mode *m*. In the bottom part of the table, we show: (i) the Kleibergen-Paap (K–P) Wald F-statistics and (ii) the *p*-value of the Anderson-Rubin (A–R) Wald test on the weak-instrument-robust inference.

tariff and trade relationship, we estimate an instrumental variable (IV) regression using two-stage least squares (2SLS). We use tariff data from 2007 as an instrument for tariffs applied in 2016. This follows a strand of existing papers in the international trade literature that instrument differences in tariffs with lagged levels of tariffs (see, e.g., Amiti & Cameron, 2012; Curzi & Pacca, 2015). The results from the first-stage regression of the IV specification suggest that our instruments are good predictors of specific tariffs in 2016, showing the relevance of the IV in explaining the (potential) endogenous variable (Table A7). Furthermore, the first-stage F-statistic rejects the possibility of weak instruments. The findings of the 2SLS regression presented in Table 7 confirm our baseline findings. The larger effect sizes suggest that our baseline findings are lower-bound estimates.

5 | CONCLUSION

An empirical regularity in international trade data is that exporters charge different FOB export prices for the same products they ship to different destinations. This holds even if we control for trade costs and destination country characteristics. Using a novel trade dataset that reports bilateral trade flows by shipping mode for multiple countries, we show that this empirical regularity is heterogeneous along a previously unexplored dimension, that is, the mode of transport. Our ordinary least squares regressions, which control for country-product-transport mode fixed effects, show that unit values increase significantly with specific tariffs. More importantly, the effects differ across transport modes. We estimate an elasticity of FOB export price to specific tariffs of 2% for air cargo, 5% for road, and .3% for sea freight. We also offer gravity-type trade cost estimates broken down by mode of transport. The positive elasticity of export price to per-unit tariffs we estimate can be driven by product quality differences or variable markups. We isolate the two mechanisms and show that for a given product quality, markups are increasing with specific tariffs. This form of price discrimination is less pronounced for higher-quality products that are predominantly shipped by air.

As UNCTAD aims to provide the GTCDIT data available on an annual basis and plans to extend the coverage, our cross-sectional analysis should be considered preliminary evidence that enables future studies to exploit time variation in analyzing within-country variations over time

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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APPENDIX A

TABLE A1 List of exporting and importing countries.

Exporters	Afghanistan, Albania, Algeria, Angola, Azerbaijan, Argentina, Australia, Austria, Bangladesh, Armenia, Belgium, Bolivia, Bosnia and Herzegovina, Brazil, Brunei Darussalam, Bulgaria, Myanmar, Belarus, Cambodia, Cameroon, Canada, Central African Republic, Sri Lanka, Chad, Chile, China, Colombia, Croatia, Cuba, Cyprus, Czechia, Denmark, Dominican Republic, Ecuador, Ethiopia, Estonia, Finland, France, Georgia, Germany, Ghana, Greece, Guatemala, Guinea, Haiti, Honduras, Hungary, Iceland, India, Indonesia, Iran, Iraq, Ireland, Italy, Côte d'Ivoire, Jamaica, Japan, Kazakhstan, Jordan, Kenya, South Korea, Kyrgyzstan, Laos, Lebanon, Latvia, Lithuania, Madagascar, Malaysia, Mali, Malta, Mexico, Mongolia, Moldova, Morocco, Mozambique, Namibia, Netherlands, New Zealand, Nicaragua, Nigeria, Norway, Pakistan, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Poland, Portugal Qatar, Russia, Saudi Arabia, Senegal, Singapore, Slovakia, Viet Nam, Slovenia, Somalia, South Africa, Zimbabwe, Spain, Sudan, Sweden, Switzerland-Liechtenstein, Syrian Arab Republic, Tajikistan, Thailand, United Arab Emirates, Tunisia, Turkey, Turkmenistan, Uganda, Ukraine, North Macedonia, Egypt, Tanzania, USA, Uruguay, Uzbekistan, Venezuela, Yemen, Zambia, United Kingdom
Importers	Albania, Algeria, Angola, Argentina, Armenia, Australia, Austria, Azerbaijan, Belarus, Belgium, Bosnia and Herzegovina, Brazil, Brunei Darussalam, Bulgaria, Cambodia, Cameroon, Canada, Central African Republic, Chile, China, Colombia, Croatia, Cyprus, Czechia, Côte d'Ivoire, Denmark, Dominican Republic, Ecuador, Estonia, Finland, France, Germany, Ghana, Greece, Guatemala, Honduras, Hungary, Iceland, India, Indonesia, Iran, Ireland, Italy, Jamaica, Japan, Jordan, Kazakhstan, South Korea, Kyrgyzstan, Laos, Latvia, Lebanon, Lithuania, Madagascar, Malaysia, Mali, Malta, Mexico, Moldova, Mongolia, Morocco, Namibia, Netherlands, New Zealand, Nicaragua, Nigeria, North Macedonia, Norway, Pakistan, Panama, Paraguay, Peru, Poland, Portugal, Qatar, Russia, Saudi Arabia, Senegal, Singapore, Slovakia, Slovenia, South Africa, Spain, Sri Lanka, Sweden, Switzerland-Liechtenstein, Tanzania, Thailand, Tunisia, Turkey, Uganda, Ukraine, United Arab Emirates, United Kingdom, United States of America, Uruguay, Viet Nam, Zimbabwe

TABLE A2 Summary statistics.

Variable	Mean	SD	Min	Max	N
Specific tariff	73.91	973.20	0	173046	840817
Ad valorem tariff	.06	.18	0	8	840817
Unit value (USD/kg)	6.93	10.04	.13	81	840817
Trade value (million USD)	1.01	13.88	0	4361	840817
Trade volume (million kg)	2.04	42.07	0	8226	840817
Colony	.07	.25			840817
Border	.10	.30			840817
Language	.15	.36			840817
FTA	.16	.36			840817
Distance (1000 km)	9.16	9.60	.13	150.41	840817

Note: The sample statistics are based on the sample used in our baseline unit value estimations. The variables colony, border, language, and FTA (i.e., free trade agreements) are dummy variables.

TABLE A3 PPML estimation results for the effect of specific tariffs on export values by mode of transport: Controlling for bilateral fixed effects.

	Export values			
	Aggregate	Air	Road	Sea
Dependent variable	**(1)**	**(2)**	**(3)**	**(4)**
log specific tariff$_{ijk}$	−.073***	−.071***	−.036**	−.080***
	(.013)	(.022)	(.018)	(.021)
Log Ad valorem tariff$_{ijk}$	−2.490***	−2.971***	−3.256***	−2.386***
	(.382)	(.480)	(.652)	(.468)
Importer-product-(transport mode) FE	Yes	Yes	Yes	Yes
Exporter-product-(transport mode) FE	Yes	Yes	Yes	Yes
Importer-exporter FE	No	No	No	No
Observations	775896	230937	229142	312777

Notes: *p* values in parentheses. ***, **, * denote significance at 1%, 5% and 10% respectively. Intercepts included but not reported. All models are estimated using the Poisson pseudo-maximum likelihood (PPML estimator). Column (1) includes importer-product-transport mode, exporter-product-transport mode, and exporter-importer fixed effects. The fixed effects in columns (2)–(4) are exporter-product, importer-product, and importer-exporter fixed effects. The dependent variable is the CIF import values from country *i* to country *j* of product *k* via transport mode *m*.

TABLE A4 PPML estimation results for the effect of specific tariffs on export volumes by mode of transport.

	Export values			
	Aggregate	Air	Road	Sea
Dependent variable	**(1)**	**(2)**	**(3)**	**(4)**
log Specific tariff$_{ijk}$	−.130***	.023	−.176***	−.147***
	(.026)	(.039)	(.037)	(.034)
log Ad valorem tariff$_{ijk}$	−3.481***	−3.965***	−5.862***	−3.773***
	(.666)	(.696)	(1.037)	(.823)
Log Distance$_{ij}$	−.665***	−.560***	−.937***	−.520***
	(.031)	(.057)	(.049)	(.060)
Colony$_{ij}$	.314***	.135	.317***	.243**
	(.054)	(.152)	(.100)	(.106)
Border$_{ij}$	.926***	−.112	1.026***	.222
	(.046)	(.166)	(.083)	(.167)
Language$_{ij}$	.181***	.226***	.262***	.037
	(.063)	(.086)	(.082)	(.114)
FTA$_{ij}$	.095	.560***	−.039	.359***
	(.081)	(.128)	(.128)	(.128)
Importer-product-(transport mode) FE	Yes	Yes	Yes	Yes
Exporter-product-(transport mode) FE	Yes	Yes	Yes	Yes
Importer-exporter FE	No	No	No	No
Observations	776646	232506	230012	314128

Notes: *p* values in parentheses. ***, **, * denote significance at 1%, 5% and 10% respectively. Intercepts included but not reported. All models are estimated using the Poisson pseudo-maximum likelihood (PPML estimator). The dependent variable is the CIF import values from country *i* to country *j* of product *k* via transport mode *m*. The fixed effects in columns (2)–(4) are country-product fixed effects.

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TABLE A5 OLS estimation results for the effect of per-unit tariffs on export prices by mode of transport (excluding intra-EU trade).

	FOB unit values	
***Dependent variable* (log)**	**(1)**	**(2)**
log Specific tariff$_{ijk}$	.010***	
	(.002)	
log Specific tariff$_{ijk}$ × Air		.014***
		(.003)
log Specific tariff$_{ijk}$ × Road		.024***
		(.007)
log Specific tariff$_{ijk}$ × Sea		.001
		(.003)
log Ad valorem tariff$_{ijk}$	.245***	.246***
	(.045)	(.045)
Importer-product-transport mode FE	Yes	Yes
Exporter-product-transport mode FE	Yes	Yes
Importer-exporter FE	Yes	Yes
Observations	586431	586431
Adj. R^2	.719	.719

Notes: *p* values in parentheses. ***, **, * denote significance at 1%, 5% and 10% respectively. Intercepts included but not reported. Both models are estimated using ordinary least squares. The dependent variable is the log of FOB unit values of exports from country *i* to country *j* of product *k* via transport mode *m*.

TABLE A6 OLS estimation results for the effect of specific tariffs on export unit values by mode of transport.

	Export values			
	Aggregate	**Air**	**Road**	**Sea**
Dependent variable	**(1)**	**(2)**	**(3)**	**(4)**
log Specific tariff$_{ijk}$	.018***	.007***	.040***	.013***
	(.002)	(.003)	(.006)	(.002)
log Ad valorem tariff$_{ijk}$	.153***	.276***	−.438**	.290***
	(.047)	(.067)	(.185)	(.059)
Importer-product-(transport mode) FE	Yes	Yes	Yes	Yes
Exporter-product-(transport mode) FE	Yes	Yes	Yes	Yes
Importer-exporter FE	No	No	No	No
Observations	775896	230937	229142	312777

Notes: *p* values in parentheses. ***, **, * denote significance at 1%, 5% and 10% respectively. Intercepts included but not reported. All models include controls for importer-product-mode and exporter-product-mode fixed effects. All models are estimated using the Poisson pseudo-maximum likelihood (PPML estimator). The dependent variable is the CIF import values from country *i* to country *j* of product *k* via transport mode *m*. The fixed effects in columns (2)–(4) are country-product fixed effects.

TABLE A7 IV estimation results: First stage.

	log Specific tariff$_{ijk}$	**log Ad valorem tariff$_{ijk}$**
***Dependent variable* (log)**	**(1)**	**(2)**
log Specific tariff$_{ijk,2007}$	.720***	−.000
	(.004)	(.000)
log Ad valorem tariff$_{ijk,2007}$	−.037	.431***
	(.057)	(.021)
Importer-product-transport mode FE	Yes	Yes
Exporter-product-transport mode FE	Yes	Yes
Importer-exporter FE	Yes	Yes
Observations	651460	651460

Notes: *p* values in parentheses. ***, **, * denote significance at 1%, 5% and 10% respectively. Intercepts included but not reported. Both models are estimated using ordinary least squares. The dependent variable is the log of FOB unit values of exports from country *i* to country *j* of product *k* via transport mode *m*.

A1 | Estimating quality following Khandelwal et al. (2013)

Consider the following CES utility function, which expresses the preferences of consumers for a variety ν in country j, assuming that consumers' preferences incorporate quality:

$$U = \left[\int_{\upsilon \varepsilon V} [\lambda(\upsilon) q(\upsilon)]^{\frac{\sigma-1}{\sigma}} \delta\upsilon \right]^{\frac{\sigma}{(\sigma-1)}} \tag{5}$$

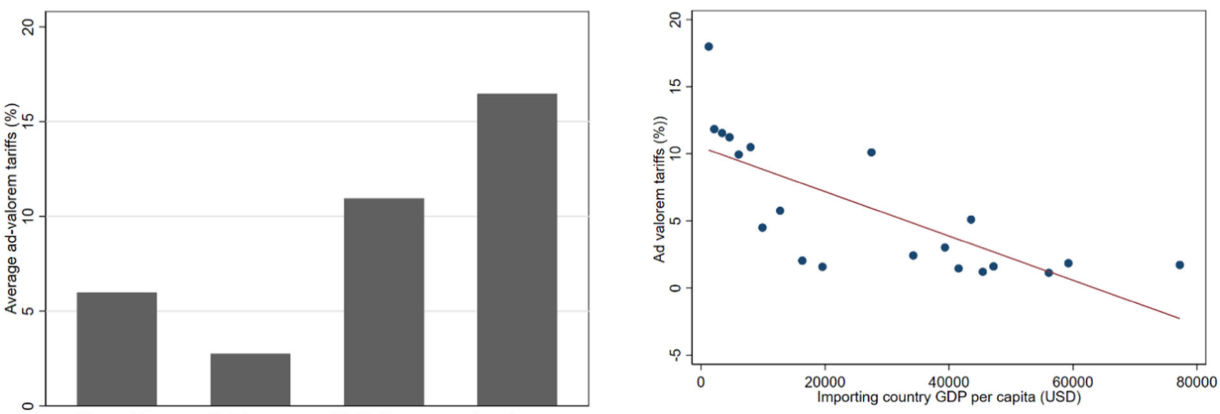
where $q(\nu)$ is the consumed quantity of ν and $\lambda(\nu)$ is its quality, while $\sigma > 1$ is the elasticity of substitution parameter which is assumed to be constant. Maximizing Equation 5 under the usual budget constraint gives the demand of consumers in importing country j for product k coming from country i as depending on the price and quality of the product, the prices of substitute products, and on the income of the consumer, yielding:

$$q_{ijkm} = \lambda_{ijkm}^{\sigma-1} p_{ijkm}^{-\sigma} P_j^{\sigma-1} Y_j \tag{6}$$

where p_{ijkm} and λ_{ijkm} are the price and the relative quality attributed by country j, to product k, exported by country i, via mode m respectively. The terms P_j and Y_j account for the importing countries' price index and income level. By log linearizing Equation 6 and moving the endogenous price to the left-hand side of the equation, we can estimate the quality for each country-product–year as the residual from the following ordinary least squares regression:

$$\log q_{ijkm} + \sigma_{jk} \log p_{ijkm} = \alpha_k + \alpha_j + \alpha_m + e_{ijkm} \tag{7}$$

where q_{ijkm} and p_{ijkm} are, respectively, the quantity and the price (unit value) of product k, exported by country i to country j via transport mode m. α_k are product fixed effects that capture differences in prices and quantities across product categories due to the inherent characteristics of products. α_j are importer fixed effects that account for both the destination price index P_j and income Y_j. α_m are transport mode fixed effects. Estimating Equation 7 separately for each country and HS4-digit industry, the estimated quality is given as $\log \hat{q}_{ijkm} = \hat{e}_{ijkm}/(\sigma_{jk} - 1)$.We allow the elasticity of substitution to differ across HS3-digit product classes using data from Broda et al. (2017).



(a) Ad valorem tariffs and income classes

(b) Ad valorem tariffs and per capita GDP

FIGURE A1 Distribution of ad valorem tariffs by income classifications.

Source: MACMAP (Guimbard et al., 2012) and World Bank WDI data.