

# BEYOND THE ICEBERG HYPOTHESIS: OPENING THE BLACK BOX OF TRANSPORT COSTS\*

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## Abstract

Following Samuelson (1954), standard models of international trade have usually modelled trade costs as an ad-valorem tax equivalent. However, many common empirical facts point out the importance of additive costs. This paper provides new empirical results that support this view. To do so, we exploit information contained in the US imports flows database over 1974-2013, distinguishing by transport mode (air and vessel). Three main results emerge. First, we show the additive component of transport costs is sizeable, with mean values over the period of 1.8% and 2.9% of the export price in air and maritime vessel transport respectively. Second, taking additive costs into account significantly improves the fit of the modelling of transport costs. Third, we show the importance of integrating the additive component in accounting for the time trend of international transport costs. Allowing for a share of additive costs varying in product/country/time dimension, we obtain that the decrease of international transport costs observed in the data is mostly attributable to a reduction in the *ceteris paribus* transport costs rather than to trade pattern composition effects. In all three aspects, our results point the importance of the additive component in accounting for international transport costs.

*JEL classification:* F14, N70, R40

*Keywords:* Transport costs estimates, transport costs determinants, non-linear econometrics, period 1974-2013, additive transport costs

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# 1 Introduction

Trade costs are central to international economic analysis. In particular, they are considered a major obstacle to international economic integration and international trade flows. According to Jacks *et al.* (2008), the trade cost decline explains around 55% of the pre-World War I trade boom and 33% of the post-World War II trade boom, while the abrupt rise in trade costs explains the inter-war trade collapse. After 1950, average trade costs fell by 16%, notably through the reduction of policy trade costs promoted through the GATT (WTO after 1995) multilateral agreements. Based on panel data, Novy (2013) finds that U.S. trade costs with major trading partners declined on average by about 40 percent between 1970 and 2000. Yet, several papers (mostly based on empirical estimates of the gravity equation) have shown that trade costs still remain a major obstacle to trade (Head and Mayer, 2004 and Disdier and Head, 2008). Using data over 1989-2000, Anderson and Van Wincoop (2004) thus estimate that average international trade costs for industrialized countries represent a 74% markup over production costs.

Defined as the costs associated with the exchange of goods across national borders, trade costs are usually split between transaction costs (information costs, contract enforcement costs, costs associated with the use of different currencies...), policy costs (tariff and non-tariff costs), time costs (time to ship goods) and transport costs *per se*. In this vein, Anderson and Van Wincoop (2004) obtain that around 30% of international trade costs are attributable to transport costs. Equivalently, international transportation costs would represent a 21% markup over production costs. Further, the sizeable elasticity of trade with respect to freight costs obtained by Behar and Venables (2011) (around -3) suggests a non-negligible impact of transport costs on trade flows. If much of trade policy barriers have been removed over the second half of the 20th century, these findings point out that the transport costs component of the overall trade costs remain large and deserve attention. This is accordingly the focus of the paper.

Following Samuelson (1954), standard models of international trade have usually modelled trade costs as an *ad-valorem* tax equivalent (ie, as a constant percentage of the producer price per unit traded, part of the “iceberg cost” hypothesis)<sup>1</sup> However, many common empirical facts support the existence of additive costs (i.e., cost per unit exported). As documented by Irarrazabal *et al.* (2015), pricing structure in shipping, additive tariffs, distribution costs... often exhibit (at least partly) an additive structure. The structure (additive vs *ad-valorem*) of transport costs is far from being anecdotal. The literature has long emphasized its role in shaping the pattern of trade flows. As pointed out by Alchian and Allen (1964), the relative price of two varieties of some good will depend on the level of trade costs as long as they display an additive component. In this context, the relative demand for more expensive/higher quality product goods increases with trade costs (“shipping the good apples out”). Lashkaripour (2017) challenges this view. He finds supporting evidence for the *ad-valorem* assumption by taking into account the fact

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<sup>1</sup>Rigourously speaking, the “iceberg cost” includes both the *ad-valorem* dimension of trade cost and the fact that these costs are paid in terms of the good that is traded. As this last element is irrelevant in our case, we use the terms “iceberg” and “*ad-valorem*” interchangeably, as commonly done in the literature.

that more expensive goods are systematically heavier and hence more costly to transport. Yet, one can be concerned by the generality of this result. Lashkaripour (2017)'s study is restricted to goods that are enumerated by items in the statistics (they represent 60% of US imports). Furthermore, while the positive correlation between weight and price seems reasonable for goods from the second industrial revolution like cars, it is dubious in the case of ITC goods which importance has been rising since 1994 (the end point of Lashkaripour's study). Besides, a number of empirical papers provide a strong empirical support to the role of additive costs in international trade costs. Based on a firm-product-level database of French exporters, Martin (2012) finds that firms charge higher unit values for exports to more remote countries, in contradiction with the ad-valorem hypothesis. Hummels and Skiba (2004) estimate the elasticity of freight rates with respect to price to be well below unity. Also, their estimates imply that doubling freight costs increases average free along-side (fas) export prices by 80 to 141 percent, consistent with high quality goods being sold in markets with high freight costs. These findings deliver strong empirical support in favor of the Alchian-Allen conjecture.

Beyond the positive aspect, several recent papers also point out the normative implications of additive trade costs. Sorensen (2014) extends Melitz (2003)'s seminal model of international trade by including additive trade costs, in addition to the ad-valorem component. A key analytical result is that the welfare gain from a reduction in trade barriers is higher for a decrease in additive costs than a decrease in ad-valorem costs.<sup>2</sup> Calibrating on Norwegian firm-level data for 2004, Irarrazabal *et al.* (2015) find that an additive import tariff reduces welfare and trade by more than an identically-sized ad-valorem tariff. While these results suggest that important welfare gains can be achieved by reducing additive trade costs, not much progress has been done in quantifying such gains. One potential reason is the lack of an empirical characterization of the additive component of trade costs.<sup>3</sup> One objective of the paper is to fill this gap.

Our paper provides an empirical decomposition of the structure of transport costs over time, by explicitly distinguishing between ad-valorem and additive parts. To do so, we exploit information contained in the US Imports flows over 1974-2013, from which we get a measure of international transport costs as the difference between the import and the export prices, on a year-product-partner country basis. Obviously, exploiting this database has drawbacks, in particular as it restricts our scope of study to the monetary dimension of international transport costs. Since our measure is based on the gap between export and import prices, it necessarily omits the other dimension of transport costs related to the time value of goods in transit. According to Anderson and Van Wincoop (2004),

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<sup>2</sup>This is due to the alteration of relative prices in a heterogeneous-firms trade framework. Lower additive trade costs reduce the export market prices of the highly performing exporters relative to lowly performing exporters and thus shift relative market shares among exporters towards the highly performing exporters - this of course does not happen with iceberg costs. Total export sales are then reallocated between a smaller number of high productivity firms. Therefore, the expected profits from exporting prior to entry increase all other things being equal by more in the case of lower per-unit costs, driving up incentives to enter the industry and bringing eventually the welfare enhancing intra-industry reallocations highlighted in Melitz (2003) framework.

<sup>3</sup>The one exception being Irarrazabal *et al.* (2015), upon which we come back later.

the 21% markup over production costs coming from transport costs includes both directly measured freight costs (10.7%) and 9% tax equivalent of “indirect” costs related to the time value of goods on their way to their export market (including holding cost for the goods in transit, inventory cost due to buffering the variability of delivery dates, preparation costs associated with shipment size...). Still, the evidence summarized in Anderson and Van Wincoop (2004) points to a persisting importance of direct transport costs, especially compared to other trade barriers. They remain more important than, e.g., policy barriers (8% tax equivalent), language barrier (7%) or information cost (6%). Hummels (1999) mentions several papers which all point that transport costs pose a barrier similar in size, or larger than tariffs. In the same vein, Limao and Venables (2001) highlight the importance of infrastructures for trade costs in general, through their impact on transport costs. Furthermore, our data is based on a single and reliable customs source with a wide time and geographical coverage, and it allows the computation of a direct transport cost measure. This limits the measurement error bias. Therefore, we strongly believe that exploiting this database may deliver useful and reliable insights on the structure of international trade costs.

By investigating the additive dimension of transport costs, our paper is related to the literature that challenges the dominant role of iceberg costs in international trade.<sup>4</sup> Closely related to our paper is the work by Irarrazabal *et al.* (2015), which develop a structural framework for inferring additive trade costs from firm-level trade data. Based on Norwegian exports in 2004, they find that the ratio of additive to ad-valorem trade costs is about 14% of the export price. Our paper complements their findings in two main respects. First, if our study covers a narrower set of trade costs focused on transport costs, our empirical analysis allows us to provide distinct measures of the levels of both the iceberg and the additive trade costs. Second, we exploit exhaustive information about the imports flows of the US over a large time span from 1974 to 2013. In this respect, our results deliver a broader view of the magnitude of additive costs in international trade over time. Despite these differences, our results share with Irarrazabal *et al.* (2015) the important role of the additive component of international transport costs.

By exploiting the time coverage of our database, our paper also relates to a second strand of the international trade literature that studies the patterns of trade costs over time, such as Hummels (2007) and Behar and Venables (2011). Many argue that transport costs have substantially decreased with technological advance in transportation, infrastructure development and new communication technologies (see Lafourcade and Thisse, 2011). Glaeser and Kohlhase (2004) find that, over the twentieth century, the cost of moving goods have declined by over 90% in real terms. However, Hummels (2007) points out the importance of the composition effects in the characterization of time trends of international transport costs. Over 1974-2004, Hummels (2007) thus obtains a stronger decline in transportation costs when the composition effects by origin country and by

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<sup>4</sup>On top of the previously cited papers about additive costs, our paper also relates to Alessandria *et al.* (2010), Hornok and Koren (2015b) or Hornok and Koren (2015a), which point out the role of per-shipment costs (among which, administrative costs) in generating some “lumpiness” in international trade transactions.

product is removed, in both air and vessel transports. Our results tend to mitigate this view. In contrast to Hummels (2007), we do not find that composition effects have offset the decrease of the “ceteris paribus” component of transport costs over time. They do not matter much in accounting for the decline of transport costs in air shipping; they even seem to have amplified the decrease in the pure transport costs in vessel shipping. Importantly, we show that the difference of results can be attributed to the role of the additive component, which modifies the decomposition of the trend reduction of transport costs between the one attributable to trade composition effects and the reduction in the “ceteris paribus” transport costs. In both air and vessel transports, we thus find that this last dimension is the main driver of the reduction of international transport costs observed over time.

Our findings can be summarized in three main points.

First, our theoretically agnostic approach provides a fairly simple (if computationally heavy) framework for measuring both ad-valorem and additive parts of transportation costs. We thus obtain that the mean values over 1974-2013 of iceberg costs are equal to 2.5% and 3.2% of the export price in air and vessel transport respectively, whereas the additive component amounts to 1.8% and 2.9%. To the best of our knowledge, our paper is the first to provide such an extensive quantitative measure of both ad-valorem and additive costs in total transport costs.<sup>5</sup> This represents a valuable insight for calibrating related international trade models.

Second, we provide an empirical assessment of what standard international trade models lose by skipping additive transport costs. Quantitatively, the omission of the additive term leads to overestimate the ad-valorem component by roughly a factor 2. On average over the whole period, biased estimates for ad-valorem are 5% for air and 6% for vessel, while unbiased estimates are respectively 2.5% and 3.2%. We also show that taking additive costs into account significantly improves the fit of the modelling of transport costs, through various measures of “goodness-of-fit”, for both transport modes and years.

Third, we exploit the time dimension of our database to document the patterns of transport costs over time. Between 1974 and 2013, we thus find that transport costs have decreased by roughly 50% in air shipping and 60% in maritime shipping, and of same order of magnitude for both additive and iceberg components. Importantly, we find that most of this decline can be attributed to a reduction in the “ceteris paribus” transport costs. Investigating this result further, we show that taking into account the additive component plays a key role in assessing the role of composition effects in the time trends of international transport costs. Allowing for additive costs that vary over time, product and partner country, we find that composition effects do not offset the decrease in the pure transport costs observed from 1974 in the time trend of overall transport costs. Put it differently, the reduction of the pure transport costs is not that strong once the role of

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<sup>5</sup>Given their database and their empirical approach, Irarrazabal *et al.* (2015) can only identify the ratio of the additive to the ad-valorem cost ( $\frac{t_{ik}}{\tau_{ik}}$  in our terminology), that they interpret by expressing it in terms of the median export price by country-product ( $\tilde{p}_{ik}$ ). By contrast, our estimation strategy enables us to uncover both values of the ad-valorem and the additive costs  $\tau_{ik}$  and  $t_{ik}$  separately, in terms of the country-product export price  $\tilde{p}_{ik}$ .

additive costs is appropriately modeled. In all three aspects, our results thus point the importance of the additive component in accounting for international transport costs.

The paper is built as follows. 2 presents our data and our methodology. In Section 3, we provide results about the size and the role of the additive component of transport costs. After reporting the mean values over the period (by transport mode), we show how introducing additive transport costs improves the modelling of transport costs. Section 4 characterizes the trends of transport costs (by transport mode) over the period 1974-2013. Section ?? provides some robustness checks of our results. Section 5 concludes.

## 2 Data Sources and Empirical Methodology

### 2.1 A measure of transportation costs

Our analysis of transportation costs consists in exploiting the difference between commodity-level export and import prices, as in Hummels (2007) (among others). The database we use to construct our measure of transport costs comes from US annual Imports of Merchandise provided by the Census bureau,<sup>6</sup> spanning from 1974 to 2013. We first use customs values, quantities and freight costs to recover free-alongside (fas) and cost-insurance-fret (cif) prices, by goods, country of origin and transportation mode.<sup>7</sup> More precisely, the (unit) fas price is computed as the total “customs value” in the US trade statistics divided by the shipping weight; in other words, it is the price for one kg of the good net of transportation costs. The cif price is then computed as the sum of the customs value and freight charges, once again divided by the shipping weight. Our dependant variable is finally computed as the ratio of the cif price divided by the fas price. Higher than 1, the variable provides a measure of transport costs as a proportion of the good’s price, an *ad-valorem* equivalent. This is a quite standard and widespread strategy, as emphasized by Anderson and Van Wincoop (2004).

Obviously, this dataset is not immune of limitations. First, it restricts our analysis to the study of international transport costs, as our measure of the cif-fas price gap only covers freight, insurance and handling costs. It is thus silent about the others dimensions of international trade costs, unlike Irarrazabal *et al.* (2015). Further, in terms of transport costs *per se*, our measure based on the cif-fas price gap omits the other dimension of transport costs related to the time value of goods in transit. According to Anderson and Van Wincoop (2004), the 21% markup over production costs coming from transport costs includes both directly measured freight costs and 9% tax equivalent of the time value of goods in transit. In this respect, this dataset embrace only a partial view of international transport barriers.

Yet, this dataset also has (at least) three advantages. First, it delivers a strong statistical reliability arising from a single, homogenous and trustworthy customs source. Based

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<sup>6</sup>More information available at: [http://www.census.gov/foreign-trade/reference/products/catalog/fl\\_imp.txt](http://www.census.gov/foreign-trade/reference/products/catalog/fl_imp.txt)

<sup>7</sup>The related literature commonly refers to the fob price rather than the fas price. While both are closely related, we refer to the fas price as the price considered by the US Foreign Trade Statistics.

on customs declarations, the US Imports database inventories all imports (both values and quantities), by country of origin, to the United states at the HS 10-digit level, with a concordance code to the SITC 5-digit coding system. This will be crucial to compute transport costs, as we detail below. In addition, the database reports information regarding freight, insurance and handling expenditures by transportation mode, ocean (or “vessel”) and air. We will make use of this to enlighten potential differences in the dynamics of transport costs across transportation mode. Second, using this dataset allows us to have both the import price and the export price for the same good (for a given origin country). This is highly valuable, as it gives us a direct measure of international transport costs (at the country/sector level), from which we can estimate separately the *levels* of both the iceberg costs and of the additive costs. Third, this dataset is available over a long time span. We are thus able to exploit information on a yearly basis from 1974 to 2013. Hummels (2007) preceded us in investigating the time dimension of this database. However, our paper differs from his work in two main respects. First, we extend the time coverage up to 2013, while Hummels (2007) stops in 2004. Second, and most importantly, we study the time trends of transport costs by disentangling the additive from the iceberg components. This proves to be key in the characterization of transport costs changes over time, in particular regarding the role of the composition effects.

We estimate international transport costs at the 3-digit classification level, even if data series on the cif and fas prices are available at the 5-digit classification level. As detailed below, the use of a nonlinear estimator triggers computational limitations that limit the level of possible detail, especially when covering a long period of time. Yet, we ensure the robustness of these results by conducting the estimations at the 4-digit level for some selected years.<sup>8</sup> Depending on the considered year, this leaves us with around 200 sectors, from approximately 200 countries of origin.

## 2.2 Empirical specification

**The estimated equation** Our purpose is to provide time-varying estimates of the size of ad-valorem and additive costs among total transport costs. To do so, we start from the equation that expresses the price  $p$  of a good paid by the importer (import, or cif price) as a function of the producer price  $\tilde{p}_{isk}$  (export, or fas price), given both per-kg ( $t$ ) and ad-valorem ( $\tau$ ) transport costs, according to:

$$p = \tau \tilde{p} + t \tag{1}$$

As usual in the literature, the iceberg trade costs are denoted  $\tau$  (with  $\tau \geq 1$ ,  $\tau = 1$  meaning no ad-valorem trade costs), while additive trade costs are labeled  $t$  (with  $t \geq 0$ ,  $t = 0$  implying no additive costs). Let us denote  $i$  the origin country, and  $k$ , the product. Trans-

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<sup>8</sup>The selected years for the 4-digit level estimations are: 1974, 1977, 1981, 1985, 1989, 1993, 1997, 2001, 2005, 2009, 2013. Comparing different levels of aggregation is useful to check differences and the presence of biases precisely due to aggregation. However, we obtain no substantial difference between the estimation results conducted at the 3 and 4-digit levels. Estimation results at the 4-digit classification level are reported in Appendix C.

forming the above equation (1) as ratio, we thus get the following baseline specification at the root of our estimation (skipping the year and transport-mode dimensions in the notations for reading convenience):

$$\frac{p_{ik}}{\widetilde{p}_{ik}} - 1 = \tau_{ik} - 1 + \frac{t_{ik}}{\widetilde{p}_{ik}} \quad (2)$$

**Estimation Strategy** We follow Irarrazabal *et al.* (2015) by considering that *i*) both ad-valorem and additive costs are separable between the origin country (*i*) and the product (*k*) dimensions, and *ii*) this separability is in a multiplicative way for the former and an additive way for the latter. In other words,  $\tau_{ik}$  and  $t_{ik}$  from Equation (2) are written as:<sup>9</sup>

$$\tau_{ik} = \tau_i \times \tau_k \quad (3)$$

$$t_{ik} = t_i + t_k \quad (4)$$

As a result, our underlying structural equation is specified as:

$$\frac{p_{ik}}{\widetilde{p}_{ik}} - 1 = \tau_i \times \tau_k - 1 + \frac{t_i + t_k}{\widetilde{p}_{ik}}$$

The ratio  $\frac{p_{ik}}{\widetilde{p}_{ik}}$  has a lower bound of one, since by construction, the cif price  $p$  cannot be lower than the fas price ( $p_{ik} > \widetilde{p}_{ik}$ ). Taking into account this constraint in the estimate suggests that the error term should be always positive and multiplicative, as in:

$$\frac{p_{ik}}{\widetilde{p}_{ik}} - 1 = \left( \tau_i \times \tau_k - 1 + \frac{t_i + t_k}{\widetilde{p}_{ik}} \right) \times \exp(\epsilon_{ik})$$

where  $\epsilon_{ik}$  follows an normal law centered on 0. Considered in logs, the above equation becomes:

$$\ln \left( \frac{p_{ik}}{\widetilde{p}_{ik}} - 1 \right) = \ln \left( \tau_i \times \tau_k + \frac{t_i + t_k}{\widetilde{p}_{ik}} - 1 \right) + \epsilon_{ik} \quad (5)$$

The non-linearity of Equation (5) implies that it cannot be estimated using standard linear estimators. All estimates are thus performed using non-linear least squares.<sup>10</sup> Yet, the use of a nonlinear estimator triggers computational limitations that limit the level of possible detail, especially when covering a long period of time. Confronted to this arbitrage, we estimate international transport costs at the 3-digit level as our benchmark classification, even though data series are available at the 5-digit classification level (*k*). In other words, this amounts making the additional assumption, that all products *k* in a 3-digit sector *s* share the same structure of costs.<sup>11</sup> This drives us to estimate a modified

<sup>9</sup>Notice that, given the magnitude or order of transport costs, assuming an additive or a multiplicative form does not make a substantial difference since, for small values (as we obtain), we have  $\tau_i \times \tau_k \simeq (\tau_i - 1) \times (\tau_k - 1) + 1$  and  $t_i + t_k \simeq (1 + t_i) \times (1 + t_k) - 1$ .

<sup>10</sup>The basis of the method is to approximate the model by a linear one and to refine the parameters by successive iterations. The intuitive criterion for convergence is that the sum of squares of residuals does not increase from one iteration to the next. See Wooldridge (2001) for more details.

<sup>11</sup>We provide a decomposition variance exercise on the observed cif-fas price. As reported in Appendix



version of Equation (5), specified as:

$$\ln \left( \frac{p_{ik}}{\tilde{p}_{ik}} - 1 \right) = \ln \left( \tau_i \times \tau_{s(k)} + \frac{t_i + t_{s(k)}}{\tilde{p}_{ik}} - 1 \right) + \epsilon_{ik} \quad (6)$$

where  $\tau_i$ ,  $\tau_{s(k)}$ ,  $t_i$  and  $t_{s(k)}$  are the parameters to be estimated, i.e., fixed effects specific to each origin country  $i$  and sector  $s$  (at the 3-digit classification level), and  $\epsilon_{ik}$  the residual centered on 0. To eliminate the potential influence of outliers, we excluded 5 percent of the upper and lower tails of the distribution in the regression variables. These cut-offs are aimed at eliminating reporting or coding errors. We estimate this equation for each year over the period 1974-2013, for each of the transportation mode reported (air or vessel), on a sectoral-origin country basis  $(i, s)$ . Depending on the year considered, this leaves us with around 800 fixed effects to estimate by transport mode (at the 3-digit level).

One key objective of the paper is to characterize the importance of additive costs relatively to ad-valorem costs. A natural way to answer this question is to perform estimations of Equation (6) constraining additive costs to be equal to zero, and compare the fitting properties and the explanatory power of the models. For each year and transport mode, we thus estimate the two models: (a) when transport costs are modeled as iceberg costs (Equation (7)), and (b) when transport costs are modeled as decomposed in the two additive and ad-valorem dimensions (Equation (8)):<sup>12</sup>

$$\ln \left( \frac{p_{ik}}{\tilde{p}_{ik}} - 1 \right) = \ln (\tau_i \times \tau_{s(k)} - 1) + \epsilon_{ik}^{ice} \quad (7)$$

$$\ln \left( \frac{p_{ik}}{\tilde{p}_{ik}} - 1 \right) = \ln \left( \tau_i \times \tau_{s(k)} - 1 + \frac{t_i + t_s}{\tilde{p}_{ik}} \right) + \epsilon_{ik} \quad (8)$$

One may be concerned that the specification of Equations (7) or (8) might be subject to endogeneity bias, as the price set by the exporter may vary depending on the transport cost burden. Studies on the pricing-to-market behavior of firms (see Krugman, 1987) show that we cannot exclude that the export price set by the firm ( $\tilde{p}_{ik}$ ) is partly endogenous to the size of transport costs (for instance, the exporting firm absorbing (part of) the transport costs by reducing the *fas* price). However, we consider as a reasonable assumption that the exporting firm cannot influence the international transport cost sector, as that would imply some a direct influence between the firm's prices and the size of transport costs, except in the choice between air and vessel transport (that is beyond our scope of analysis). Otherwise stated, conditional to an export price and a transport mode, the gap between

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B.2, the share of the observed variance that is accounted for by the between-sector ( $s$ ) variance is roughly similar to the between-product ( $k$ ) variance.

<sup>12</sup>One may also object that a comprehensive study of the structure of transport costs should also include the third model with only additive costs. This has driven us to estimate this model as well, in which case the estimated equation is written according to:  $\ln \left( \frac{p_{ik}}{\tilde{p}_{ik}} - 1 \right) = \ln \left( \frac{t_i + t_{s(k)}}{\tilde{p}_{ik}} \right) + \epsilon_{ik}^{add}$ . The main result that emerges is that the model with additive costs only is dominated (in terms of quality of fit properties) by the model with multiplicative costs only (Equation (7)), which is itself dominated by the complete model (Equation (8)), anticipating on further results. These results are reported in the Online Appendix, available on the authors' webpages.

the export price declared to the custom data and the import price recorded by the US administration is beyond the firm’s control. In this respect, we are confident that our estimation strategy is immune from endogeneity problems.

After estimating Equation (8), we can re-build a measure of each component,  $\hat{\tau}_{is}^{adv} = \hat{\tau}_i \times \hat{\tau}_{s(k)}$  for the ad-valorem cost and  $\hat{t}_{is} = \hat{t}_i + \hat{t}_{s(k)}$  for the additive cost, that are country-sector specific, by year and transport mode. When assuming iceberg costs only (Equation (7)), we proceed similarly to get  $\hat{\tau}_{is}^{ice} = \hat{\tau}_i \times \hat{\tau}_s$ .<sup>13</sup> Similarly as Irarrazabal *et al.* (2015), we take the average over the sector-country dimension, using the values of each trade flow (*is*-specific) over total yearly trade as a weighting scheme. We thus recover a “synthetic estimate” of each type of transport cost: a)  $\hat{\tau}^{ice}$ , b)  $\hat{\tau}^{adv}$  and  $\hat{t}$ , for each year and transportation mode. These results are reported in Section 3.

### 3 Decomposing Transport Costs: The importance of the additive component

The objective of this section is twofold. First, we quantify the magnitude of transport costs over time (by transport mode), distinguishing whether the additive component  $t_{ik}$  is excluded or included in the estimated equation (Equation (8) or (7)). Second, we assess the importance of the additive component of in overall transport costs through goodness-of-fit measures.

#### 3.1 Decomposing transport costs over 1974-2013

Our first contribution to the literature is to provide estimates for the size of both the ad-valorem and the additive components of transport costs. Table 1 reports a summary of our results. It displays the mean and median values of each type of trade costs (either ad-valorem estimated alone or estimated along with additive costs), as well as the associated standard deviation, averaged over the period 1974-2013, for estimation driven both at the 3- and 4-digit sectorial level for different specifications and data. The first panel reports the results for a specification based on ad-valorem costs estimated alone, while the second panel presents estimates for a specification involving both ad-valorem and multiplicative component. Finally, the third panel reports the same set of descriptive statistics, but for the actual cif/fas ratio in our data.<sup>14,15</sup>

Table 1 calls for two types of comments. Starting with pure statistical concerns, it appears that mean values are systematically higher than medians - by around one percentage point. This result is not surprising recalling that our key variable is by nature bounded to

<sup>13</sup>In this case, notice that the equation could be estimated relying on a linear form. To preserve comparability of the results, we keep the same non-linear estimation method in both cases though.

<sup>14</sup>In Appendix B, we report similar results for a sample of years, for both transport mode, at the 3 and 4-digit classification level. Results for all years (available at the 3-digit level) are available upon request to the authors.

<sup>15</sup>We present the results for air at the 3-digit level removing the year 1989, as the estimation results reveal the presence of strong outliers that bias the estimates of transport costs upwards. Overall results (over the whole period) are not substantially affected if this year is included though. These results are available upon request to the authors.

Table 1: Transport costs estimates: Summary

Mean value over 1974-2013				
# digit	3 digits		4 digits (*)	
Mode	Vessel	Air (**)	Vessel	Air
<b>Model (A) - With only Ad-Valorem Transport Costs (<math>\hat{\tau}^{ice}</math>, in %)</b>				
Mean	5.8	5.1	6.0	4.9
Median	5.1	4.2	5.2	3.7
<b>Model (B) - With Additive &amp; Ad-Valorem Transport Costs</b>				
<i>Ad-valorem term (<math>\hat{\tau}^{adv}</math>, in %)</i>				
Mean	3.2	2.5	3.3	2.4
Median	2.8	1.8	2.8	1.6
<i>Additive term (<math>\hat{t}^{add}/\tilde{p}</math>, in %)</i>				
Mean	2.9	1.8	2.8	1.9
Median	1.9	0.7	1.7	0.8
<b>Data (<math>p/\tilde{p}</math>, in %)</b>				
Mean	5.3	5.0	5.6	3.9
Median	4.3	2.0	4.4	1.9
# obs.	29279	28207	29317	27680
# origin country	188	191	188	189
# products	230	211	666	567

Notes: Statistics are obtained weighting each observation by its value relative to total trade flows. The additive term is expressed in fraction of fas price. (\*): Four 4-digit estimation: 0n selected years. (\*\*): 1989 omitted in 3-digit estimation for air.

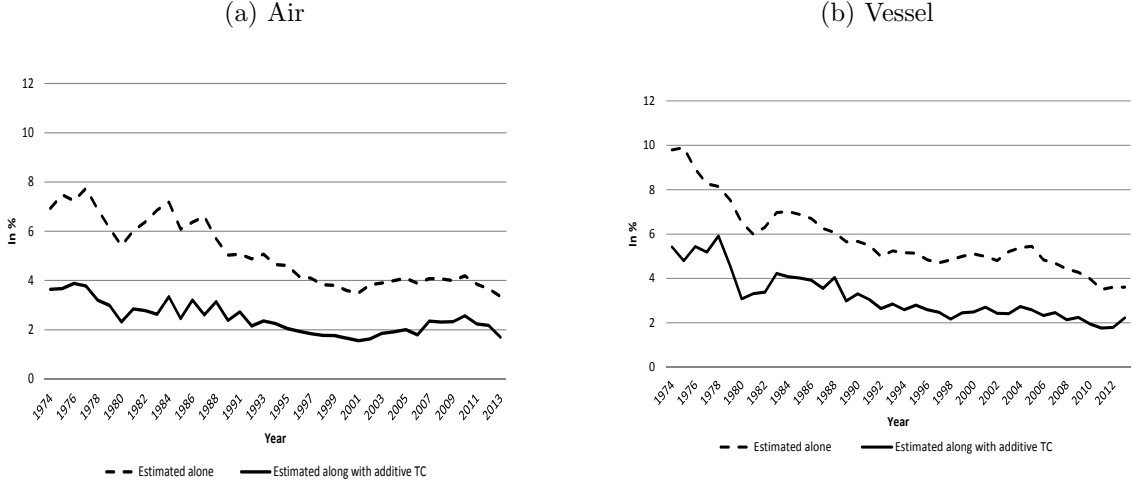
0; therefore, outliers can only be positive, pushing the mean up compared to the median. One can also note that estimated total costs are also systematically higher than observed costs by 0.5 to 1 percentage point. This is first due to the fact that observed data are *de facto* trade-weighted (i.e., by the weight of each good among total trade), while our estimates are based on simple arithmetic means - Section 4 will go into more details of these compositions effects. Furthermore, Table 1 reports values/percentages, whereas all our estimates are based on log-linearization. Therefore, what matters on the statistical ground is that the mean of our predicted values (based on logarithms) must be equal to the mean of the log-linearized data ( $\ln\left(\frac{p_{ik}}{\tilde{p}_{ik}} - 1\right)$ ), which does not necessarily imply equality between values. Descriptive statistics showing that it is indeed the case are available upon request to the authors.

Coming now to interpretation, Table 1 shows that the magnitude of overall transport costs is sizeable. When modeled as ad-valorem costs only (Model (A)), they correspond to a mean increase of the export price by 5.8% for vessel shipping, and by 5.1% for air shipping over 1974-2013. Furthermore, when decomposing transport costs into an additive and an ad-valorem component, we find that the per-kg cost dimension is sizeable. Over the whole period, additive costs are 2.9% of the export price for ocean shipping - with a lower estimated value for the ad-valorem freight rate of 3.2%. These values are respectively equal to 1.8% and 2.5% for air shipping. For both transport modes, the omission of the additive term seriously biases the ad-valorem term upward. In quantitative terms, the omission of the additive term leads to overestimate the ad-valorem component by roughly a factor 2.

We extend further our analysis by using explicitly the time dimension of our dataset in order to assess the dynamics of our estimates over time. Figure 1 thus reports the

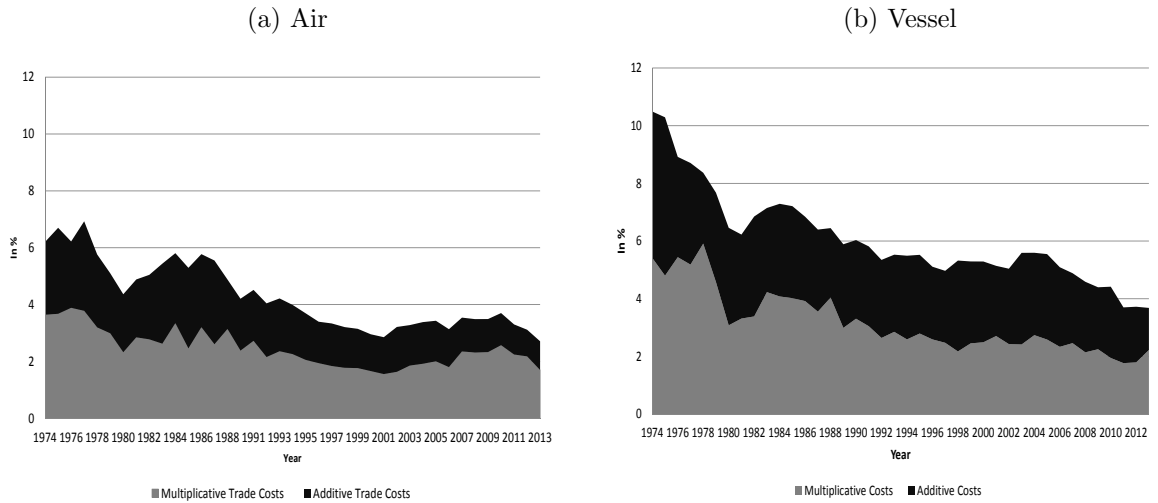
mean value of the ad-valorem component, estimated alone (Dashed line, corresponding to Equation (7)) and along with the mean value of the additive component (Plain line, corresponding to Equation (8), by transport mode.

Figure 1: Ad-valorem Costs (Yearly mean value, 3 digits, in % of the fas price)



From Figure 1, we can infer that the sizeable magnitude of additive costs also holds across years. Further, Figure 1 reports that for air shipping, the size of the bias seems to decrease over time, while it appears rather stable for vessel shipping. Put it differently, this suggests that the share of the additive component in total transport costs has decreased over time for air shipping. To get a better picture on this, we study the shares of both ad-valorem and additive components in total costs, by transport mode and over time, based on Figure 2.

Figure 2: Decomposing Transport costs (Yearly mean value, 3 digits, in % of the fas price)



As reported on Figure 2, total transport costs have regularly declined over time, by an order of magnitude of 3 percentage points in air shipping and 5 percentage points

in ocean shipping (basically, divided by 2 in both cases). The overall trend pictured in these estimates is in line with the findings by Hummels (1999), who points out that overall transport cost for the United States declined from 6 % to 4 % between 1974 and 1996. For the same years, we obtain a total decrease from 6.9 to 4.2% on average for air shipping, and from 9.8% to 4.8% for ocean shipping.<sup>16</sup> The fact that our estimates are on average higher than those by Hummels (1999) (in ocean shipping mostly) is not necessarily surprising, given that ours being simple averages, whereas Hummels (1999)'s are trade-weighted. Overall, our results display trends that are close to those reported by Hummels (1999), with a magnitude of transport costs that appears higher in ocean shipping than for air transport over the period.

Our empirical strategy allows us to go beyond these results, by distinguishing within these evolutions between multiplicative and additive transport costs. First, the decreasing trend holds considering ad-valorem costs alone (Figure 1), as well as in presence of additive costs (Figure 2). Second, in both transport modes, the additive component appears of sizeable importance. As mean value over the period, it amounts to 48.2% of total transport costs in Vessel, and 42.3% in Air. Further, the downward trend in overall transport costs over time can be attributed to both the additive and the ad-valorem components, with a share of additive costs roughly constant over time. These results thus suggest that additive costs are neither negligible in magnitude nor an erratic phenomenon. By contrast, they represent an sizeable and structural dimension of international transport costs.

At this point, let us compare our results to the literature. First, consider our estimation of the overall size of transport costs. From Table 1, we obtain an overall value of approximately a 6% markup in ocean shipping, 5% markup in air shipping.<sup>17</sup> If this seems modest in comparison with the 11% of markup obtained by Anderson and Van Wincoop (2004) over a set of industrialized countries, this stands in line with the results obtained by Hummels (2007) for the US economy.<sup>18</sup>

Second, consider our results specific to the additive costs dimension. These can be compared to Irarrazabal *et al.* (2015), which provide the most recent evidence on the size of the additive costs. More precisely, based on Norwegian trade data for 2004, Irarrazabal *et al.* (2015) estimate that the ratio of additive to ad-valorem trade costs amounts to 14%

<sup>16</sup>One may be puzzled for by the high magnitude of estimates for the beginning of the period (until 1980 approximately) for ocean transport. Hummels (2007) finds similar outcomes on tramp prices indexes, and suggests the oil shock as a likely culprit, in a context where technological progress was quicker in aviation than in vessel, allowing a better dampening of oil shocks on air freight rates.

<sup>17</sup>Expressed as a markup over production costs, transport costs are equal to  $\frac{p-\tilde{p}}{\tilde{p}}$ . Under Model (A) (ad-valorem costs only), making use of the figures reported in Table 1 gives a markup of 5.8% in vessel, and 5.1% in air shipping (considering the mean value over the period). Under Model (B), total transport costs are equal to  $\frac{p-\tilde{p}}{\tilde{p}} = (\tau - 1) + \frac{t}{\tilde{p}}$ . With  $\tau - 1 = 0.032$  and  $\frac{t}{\tilde{p}} = 0.029$  in Vessel (as reported in Table 1), we get a value equal to 6.1% in Vessel. A similar calculus gives 4.3% in air transport.

<sup>18</sup>The difference of results with Anderson and Van Wincoop (2004) can be accounted for by a number of reasons. Anderson and Van Wincoop (2004) obtain this 11% markup as a rough value by aggregating various sources over a bunch of industrialized countries, with data mostly based on the second half of the 1990s. By contrast, our estimation of a 6% markup relies on a single source of data based on the US imports flows over 1974-2013. Beyond country coverage, or the time sample, another plausible candidate explanation lays in the difference of empirical methodology: Anderson and Van Wincoop (2004)'s estimates are based on standard gravity equations, while ours come from a non-linear estimation of a "structural" decomposition of the difference between export and import prices.

of the export price, ie  $\frac{t/\tau}{p} = 14\%$  expressed in our terminology. In contrast to them, we can provide separate estimates for each cost component (additive and ad-valorem), from which we can rebuilt the ratio in similar terms to them – allowing us to gain in generality in this respect. Making use of our estimates for 2004, we thus obtain a ratio  $\frac{t}{\tau p} = 2.8\%$  in ocean shipping, 1.8% in air transport.<sup>19</sup> This may sound surprisingly low, in contrast to the 14% obtained by Irarrazabal *et al.* (2015). However, while the database of Irarrazabal *et al.* (2015) allows to study trade costs in general, our database covers a subset made of the monetary international transport costs (as we start from the gap between the import and the export prices). From Anderson and Van Wincoop (2004), we can infer that monetary transport costs approximatively represent 15% of total trade costs.<sup>20</sup> Plugging this into Irarrazabal *et al.* (2015) results, allows to deduce a ratio  $t/\tau$  of international transport costs equal to 2.1% ( $0.15 \times 0.14$ ), which is in line with our own results. This makes us confident in our quantitative assessment of the size of the additive component in international transport costs. In the next section, we analyze their importance through another angle based on quality-of-fit diagnostic tests.

### 3.2 Assessing the importance of additive transport costs

In this section, we explore the performances of each type of model (with and without additive costs) in fitting the observed cif-fas prices gap, in order to deliver a more systematic diagnosis about the importance of additive costs. To do so, we rely on several standard measures of fit. The first indicator is through comparing  $R^2$ . However, its use is far from being straightforward when evaluating non-linear estimates.<sup>21</sup> This drives us to complement the goodness of fit diagnosis with three alternative measures. We provide the Standard Error of Regression (SER), which represents the average distance that the observed values fall from the regression line. The smaller the SER value, the better the quality of fit, as it indicates that the observations are closer to the fitted line. We also report the log-likelihood function, and two measures derived, the Akaike Information Criterion (AIC) and the log-likelihood (LL) ratio test. A decrease in the log-likelihood function points to a better quality-of-fit. However, the likelihood function systematically decreases with the number of parameters included; the AIC criterion allows for correcting this overfitting by including a penalty in the computation of the statistic.<sup>22</sup> The preferred model is the one with the minimum AIC value. Finally, the log-likelihood ratio test statistic compares systematically the likelihood of the Unrestricted model ( $UR$ , including the additive term, i.e. Equation (8) and the Restricted one ( $R$ , i.e. Equation (7)). The null

<sup>19</sup>On average over the whole period, from the figures in Table 1, we have  $\frac{t}{\tau p} = \frac{\bar{t}}{\bar{\tau}} = \frac{0.029}{1.032} = 2.8\%$  in vessel; and 1.8% in air shipping.

<sup>20</sup>Anderson and Van Wincoop (2004) estimate that monetary transport costs represent a 11% markup over production costs, and that total international trade costs represent 74%, so transport costs amount to  $11/74 = 15\%$  of total trade costs.

<sup>21</sup> $R^2$  is based on the underlying assumption that the adjusted model is a linear one. In a non-linear context,  $R^2$  is strictly speaking inappropriate. However, if the error distribution is approximately normal, a standard metric like  $R^2$  remains informative on the quality of adjustment.

<sup>22</sup>Precisely, the AIC stat is equal to  $2 \times \text{number of parameters} - 2 \times \text{Likelihood}$ , the number of parameters being given by the number of restrictions.

tested is that the two models are statistically equivalent. Results are reported in Tables 2 and 3, for Air and Vessel respectively, at the 3-digit level.

Table 2: Air: Measures of Goodness-of-fit (3 digits)

Year	1974	1980	1990	2000	2010	2013	Mean stat
$R^2$							
Model (A)	0.30	0.27	0.25	0.32	0.42	0.34	0.31
Model (B)	0.59	0.65	0.63	0.64	0.51	0.46	0.60
<b>SER</b>							
Model (A)	0.79	0.86	0.81	0.84	0.86	0.92	0.85
Model (B)	0.67	0.71	0.67	0.70	0.79	0.85	0.73
<b>AIC criteria</b>							
Model (A)	35674.98	41170.98	60715.58	87492.55	102297.66	88191.87	70498.1
Model (B)	31387.29	35738.39	52098.91	74954.88	95887.05	80873.72	62285.0
<b>Log-likelihood</b>							
Model (A)	-17530.5	-20253.5	-29977.8	-43341.3	-50746.8	-43692.9	-34888.6
Model (B)	-15125.6	-17263.2	-25393.5	-36788.4	-47277.5	-39751.9	-30508.3
LL ratio	4809.7	5980.6	9168.7	13105.7	6938.6	7882.1	8760.69
nb of restrictions	355	369	393	426	426	427	402
p-value	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Notes: Model (A) = with only ad-valorem transport costs. Model (B) = with additive & ad-valorem transport costs. SER = Standard Error of regression; AIC = Akaike Information Criterion.  $R^2$  between the log of predicted ratio and the log of the observed ratio. For the LL ratio test, the number of restrictions is equal to the number of parameters estimated, i.e., the number of partner countries plus the number of products. The mean statistics calculated as the average value over all years.

Table 3: Vessel: Measures of Goodness-of-fit (3 digits)

Year	1974	1980	1990	2000	2010	2013	Mean stat
$R^2$							
Model (A)	0.45	0.42	0.46	0.40	0.35	0.34	0.39
Model (B)	0.61	0.58	0.59	0.57	0.49	0.46	0.56
<b>SER</b>							
Model (A)	0.58	0.62	0.59	0.65	0.74	0.76	0.66
Model (B)	0.48	0.53	0.51	0.55	0.66	0.68	0.57
<b>AIC criteria</b>							
Model (A)	33328.8	33010.3	51142.6	71365.9	84789.9	88191.9	57848.6
Model (B)	27331.5	28067.3	43664.7	60475.9	76161.3	80873.7	49682.3
<b>Log-likelihood</b>							
Model (A)	-16287.4	-16129.1	-25169.3	-35263.9	-41998.9	-43692.9	-28534.3
Model (B)	-12985.8	-13353.7	-21171.4	-29491.0	-37418.7	-39751.9	-24151.3
LL ratio	6603.28	5550.96	7995.88	11545.98	9160.56	7882.15	8766.0
nb of restrictions	393	395	411	436	424	427	417
p-value	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Notes: Model (A) = with only ad-valorem transport costs. Model (B) = with additive & ad-valorem transport costs. SER = Standard Error of regression; AIC = Akaike Information Criterion.  $R^2$  between the log of predicted ratio and the log of the observed ratio. For the LL ratio test, the number of restrictions is equal to the number of parameters estimated, i.e., the number of partner countries plus the number of products. The mean statistics calculated as the average value over all years.

Tables 2 and 3 lead to the same conclusion: The inclusion of the additive term leads to an improvement of the quality of fit, whatever the considered criterion or the transport mode. On average over the whole period, the  $R^2$  doubles when per-kg costs are included for Air, and increases by 50% for Vessel. Similar qualitative conclusions arise from the comparisons of the standard errors of the regression (SER). Regarding the other criteria, improvements allowed by the inclusion of the additive term are roughly of the same extent across transport modes. Both AIC and Log-Likelihood statistics decrease with the

inclusion of the additive term, and the log-likelihood test unambiguously rejects the null of statistical equivalence of the two models. These results holds whatever the considered year.

For comparison purposes, we provide a similar goodness-of-fit exercise at the 4-digit product level (4-digits), reported in in Appendix C, Tables 8 and 9. If anything, the quality of fit appears slightly higher when estimations are based on the 4-digit classification. This is especially true for the model restricting transport cost to their ad-valorem dimension, whatever the transport mode considered. When the additive part is taken into account however, the difference in goodness of fit between the 3- and the 4-digit classification level becomes very small, whatever the considered criterion. In other words, if using a more disaggregated classification unsurprisingly adds some statistical precision, this is not to an extent that would disqualify the use of slightly more aggregated data. Further, the same conclusion established at the 3-digit level regarding the significant role of the additive components in fitting international transport costs emerges at the 4-digit level.

## 4 Decomposing Transport Costs: Characterizing the trends

### 4.1 Estimation strategy

In this section, we investigate the role of the additive component in total transport costs in a historical perspective. As a first step, we come back to Figure 2, that displays the respective shares of additive and iceberg components in transport costs over time by transport mode. Considering the trend in total transport costs (the upper line in Figure 2), both air and vessel shipping exhibit a downward trend in overall transport costs since 1974 (-2.1% per year for mean air transport costs and -2.0% per year for mean ocean transport costs).<sup>23</sup>

Before making any definite statement about this though, it is worth emphasizing that the time trend of international transport costs depends on both *i*) the evolution of per product and per partner “ceteris paribus” transport costs and *ii*) the evolution of the composition of trade. Total transport costs may thus have decreased over time because the share of neighbor countries in total US trade or the share of goods cheaper to transport has increased (explanation *ii*)), independently of any change in transport costs *per se*. As emphasized by Hummels (2007), it is hence necessary to eliminate the composition effects of trade flows to isolate the evolution of “ceteris paribus” international transport costs, i.e. per product- and per partner- transport costs.

If we share this view with Hummels (2007), we adopt a different strategy for eliminating composition effects, which builds upon our first-stage results.<sup>24</sup> Estimation driven in Section 3 indeed provides us with the additive and ad-valorem measures of international transport costs (Equation (6)), that vary over time, product and origin country. Starting

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<sup>23</sup>One may worry that this result springs from high oil-shock related transport costs in 1974. However, computing the time trends from 1980 does not dramatically change the picture. The yearly trend from 1980 is -2% for mean air transport costs and -1.6% for mean vessel transport costs. We thus choose to exploit the whole time dimension of our database by taking 1974 as starting date of our time trend analysis.

<sup>24</sup>See Appendix for a detailed comparison of Hummel’s (2007) methodology and ours.



from these values, we extract the “ceteris paribus” transport cost component (additive and multiplicative, by transport mode) by the mean of a time fixed effect (see details below). By comparing the additive cost component unfitted (total) and fitted (composition effects excluded), we characterize if this dimension of the transport cost has fallen due to (for instance) the fact that product quality has increased over time (weight has reduced, hence reducing the transport cost by dollar transported), or if it is the “ceteris paribus” additive costs (for instance, handling costs) that have reduced over time. We proceed similarly for the multiplicative component of trade costs. We also agglomerate the two components (additive and iceberg) in a unified measure of transport costs. This allows us to compare how “ceteris paribus” transport costs have changed over time, composition effects excluded, and to compare them to the unfitted ones.<sup>25</sup>

This empirical strategy differs from Hummels (2007) in two (interrelated) main dimensions. First, our characterization of the time trends in transport costs identifies the trend patterns of the transport costs (composition effects excluded) for both the additive and ad-valorem costs, as well as for the overall transport cost. Second, and as direct consequence, our methodology lets the ratio between the additive and the ad-valorem components of transport costs vary over the three time-product-partner country dimensions. This turns out to be of primary importance in the disentangling in the time trend of transport costs, what comes from the composition effects and what comes the “ceteris paribus” transport cost dimension, as we show below.<sup>26</sup>

## 4.2 Empirical specification

Our strategy to eliminate the composition effects follows the following rationale. As explained above, we start from the values of each additive and ad-valorem transport cost measure estimated in our first stage. We measure how these costs have changed over time by assuming a composition of trade flows by country partner and product that is constant throughout the period, and equal to the one observed in 1974. One advantage of this method is to yield measures of transport costs (fitted and unfitted) that are easily comparable between transport modes and transport cost components.

This can be described as a two-stage process. First, we decompose the measure of transport costs component in the three product/country/time dimensions, using fixed effects. For the estimated ad-valorem component, we thus estimate the following equation:

$$\ln(\hat{\tau}_{ikt}) = \delta + \underbrace{\sum_{i \neq \text{ARG}} \alpha_i \mathcal{K}_i}_{(a)} + \underbrace{\sum_{s(k) \neq 011} \beta_{s(k)} \mathcal{K}_{s(k)}}_{(b)} + \underbrace{\sum_{t \neq 1974} \gamma_t \mathcal{K}_t}_{(c)} + \epsilon_{ikt} \quad (9)$$

where  $\mathcal{K}_i$  and  $\mathcal{K}_{s(k)}$  represent country- and sector- fixed effects. Equation (9) is estimated using OLS, with a weighting scheme based on the value of each flow in the total value of

<sup>25</sup>Note that these “unfitted” total transport costs are virtually the same as those reported in Figure 2, but reported from another perspective (basis 100 in year 1974).

<sup>26</sup>Rigourously speaking, our methodology also differs from Hummels (2007) with respect to the weighting scheme used to obtain the evolution of the “ceteris paribus” transport costs over time. We discuss this point with more details in Appendix D.

flows the considered year. We cannot use the same equation for the estimated additive component, as by construction, the sector fixed effect and the country fixed effect are additive rather than multiplicative. We estimate the following equation using non-linear least squares:<sup>27</sup>

$$\ln(\hat{t}_{ikt}) = \ln \left( \delta + \underbrace{\sum_{i \neq \text{ARG}} \alpha_i \mathcal{K}_i}_{(a)} + \underbrace{\sum_{s(k)} \beta_{s(k)} \mathcal{K}_{s(k)}}_{(b)} \right) + \underbrace{\sum_{t \neq 1974} \gamma_t \mathcal{K}_t}_{(c)} + \epsilon_{ikt} \quad (10)$$

As displayed in Equations (9) and (10), the objective is to decompose the estimated transport cost component in three components: the country dimension (Term (a)), the product dimension (Term (b)) and the “ceteris paribus transport costs time trend” (Term (c)). Notice that Equations (9) and (10) preserve our specification of the ad-valorem and additive costs of Equations (3) and (4), as we consider that the iceberg cost is the product of the country of origin and the good dimension, while the additive cost is the sum of the two dimensions.<sup>28</sup> Both equations are estimated by transport mode.

In this exercise, we are interested in isolating the change in the time dimension of the each transport cost component. This constitutes our second stage. As for the ad-valorem component defined in  $[1; +\infty]$ , from the estimation of Equation (9), we built the variable  $\Gamma_t^{adv}$ , for each year  $t \geq 1974$ , according to:<sup>29</sup>

$$\Gamma_t^{adv} = 100 \cdot \frac{\bar{\tau}_{1974} \cdot \exp(\gamma_t) - 1}{\bar{\tau}_{1974} - 1} \quad (11)$$

with  $\bar{\tau}_{1974} = \exp(\delta + \sum_i \alpha_i + \sum_s \beta_s)$  the mean ad-valorem transport cost in 1974. In plain words, we measure how these costs have changed over time by blocking the composition of trade flows by product and country partners to the one observed in 1974 (the beginning of our sample).

As for the additive cost defined in  $[0; +\infty]$ , we built the variable  $\Gamma_t^{add}$ , the reference year being 1974 (ie, with  $\gamma_{1974} = 0$ ) according to:

$$\Gamma_t^{add} = 100 \cdot \exp(\gamma_t) \quad (12)$$

As a result, the two series (for  $\Gamma_t^{adv}$  and  $\Gamma_t^{add}$ ) have a straightforward interpretation in percentage changes from the initial value of 100 for  $t = 1974$ .

Last, we rebuild a measure of total transport costs as the sum of the two components (additive and iceberg), on both the “raw” (without composition effects excluded) and the

<sup>27</sup>For sake of notational simplicity, we do not distinguish the coefficients associated to the fixed effects between Equations (9) and (10), even if they are specific to the type of transport costs considered (e.g., the series of  $\gamma_t$  differs from one estimation to the other). Note that we impose the same weighting scheme as for the OLS regression (based on the relative value of the flow).

<sup>28</sup>In the three estimations (ad-valorem costs alone, ad-valorem costs estimated along with additive, and the additive component), we consider Argentina, the sector 011 and the first year of our dataset 1974, as references for the country-, product and -year dummies.

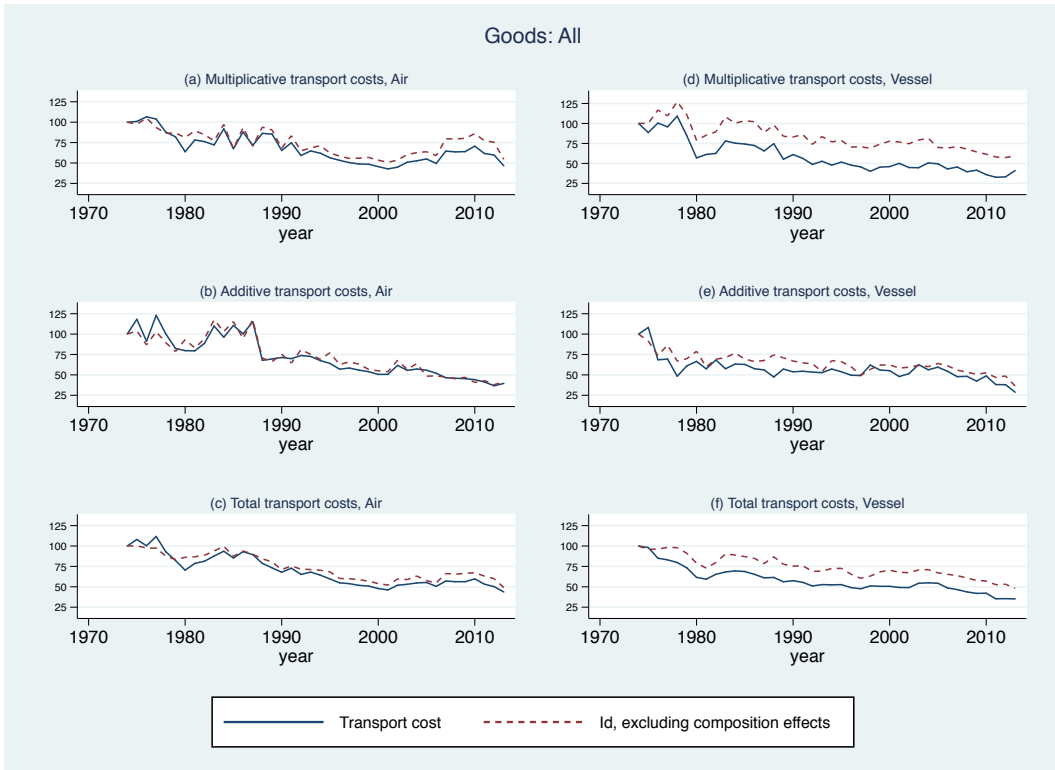
<sup>29</sup>See details in Appendix D.

“ceteris paribus” estimated transport costs (composition effects excluded, see Appendix D).

### 4.3 Characterizing the time trends in transport costs

Figure 3 reports the results.<sup>30</sup> In Panels (a) and (b), we report the time changes of the ad-valorem costs and the additive costs respectively. Panel (c) displays the time changes in the total transport costs (built as the sum of the two components as detailed above). In the three cases, the series are reported as indices, starting from the reference value 100 in 1974 and by transport mode.

Figure 3: Transport costs (with and without composition effects)



Three main results emerge from Figure 3. First, echoing the related literature (see Lafourcade and Thisse, 2011), we find that international transport costs have substantially decreased over the period, and in both transport modes. International transport costs were reduced by 50% between 1974 and 2013 in air shipping, and by 60% in maritime shipping. Second, the magnitude of the decrease is roughly of same order both the ad-valorem and the additive components. Third, we do not find evidence of a significant difference between the raw transport costs and the “ceteris paribus” transport costs in Air transport, for both the additive and ad-valorem components (Figure 3, left panels). Air transport costs were reduced by 50% between 1974 and 2013, and this is mainly attributable to a reduction in the “ceteris paribus” transport costs. Composition effects are more pronounced in vessel

<sup>30</sup>In Appendix D, we report the results at a more disaggregated level, distinguishing between primary and manufacturing goods.

transport. Considering the raw series, maritime transport costs have decreased by 60% over the period, which can be decomposed in a 50% decrease in transport costs *per se*, and a 10% reduction that comes from composition effects. Precisely, the role of composition effects is significant for the multiplicative component, whereas the reduction in the additive costs is mostly attributable to changes in “*ceteris paribus*” additive costs.

This last set of results stands in sharp contrast with Hummels (2007), which obtained that the “*ceteris paribus*” transport costs had decreased more than the unfitted ones (over 1973-2004), suggesting an important role to composition effects. If anything, we find the opposite result here. Investigating this difference of result further (see Appendix D), we find that this can be explained by the difference in methodology, and primarily the treatment of the additive component transport costs. Assuming a varying share of the additive component over time, product and country partner indeed modifies the decomposition of the trend reduction of transport costs between the one attributable to trade composition effects and the reduction in the “*ceteris paribus*” transport costs. In both air and vessel transports, we thus find that this last dimension is the main driver of the reduction of international transport costs observed over time, in particular in vessel transport.

## 5 Conclusion

This paper empirically studies the magnitude of additive (or per-kg) costs in international transport costs, by exploiting the differences between the import and the export prices. Using SITC 3 and 4- digit cif-fas unit values taken from the US import database over 1974-2013, we estimate the two components of transport costs, by transport mode (air or ocean). Our results may be summarized in three main findings. First, we provide a quantitative measure of both the additive and the iceberg transport cost. We thus find that additive costs amount to 2.8% of the export price unit values for ocean shipping, and ad-valorem ones 3.2%, as mean values over 1974-2013. These values are respectively equal to 1.8 and 2.5% for air transport. Second, we show that taking additive costs into account improves the fit of the modelling of transport costs. All goodness-of-fit measures point out to this conclusion, which holds for both transport modes and all years considered. Third, we show the importance of integrating the additive component in accounting for the time trend of international transport costs. Allowing for a varying share of additive costs in product/country/time dimension, we obtain that the decrease of international transport costs observed in the data is mostly attributable to a reduction in the *pure* transport costs rather than to trade pattern composition effects. In all three aspects, our results point the importance of the additive component in accounting for international transport costs.

Our results could be extended in two main ways. On the empirical side, one may want to go deeper in the “structural” determinants of trade costs, i.e. identify the respective roles of handling costs, insurance and freight at the root of the gap between export and import prices. On the theoretical side, our results can be used to explore the role of additive costs in shaping international trade flows (in an international trade theory perspective) and in affecting the international transmission of business cycles. This is left for further

research.

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## A Data Appendix

The Customs value is the value of imports as appraised by the U.S. Customs and Border Protection in accordance with the legal requirements of the Tariff Act of 1930, as amended. This value is generally defined as the price actually paid or payable for merchandise when sold for exportation to the United States, excluding U.S. import duties, freight, insurance, and other charges incurred in bringing the merchandise to the United States. The term “price actually paid or payable” means the total payment (whether direct or indirect, and exclusive of any costs, charges, or expenses incurred for transportation, insurance, and related services incident to the international shipment of the merchandise from the country of exportation to the place of importation in the United States) made, or to be made, for imported merchandise by the buyer to, or for the benefit, of the seller. In this respect, the “custom value” corresponds to the fas price (“free-alongside” price) delivered by the seller.

The import charges represent the aggregate cost of all freight, insurance, and other charges (excluding U.S. import duties) incurred in bringing the merchandise from alongside the carrier at the port of exportation in the country of exportation and placing it alongside the carrier at the first port of entry in the United States. In the case of overland shipments originating in Canada or Mexico, such costs include freight, insurance, and all other charges, costs and expenses incurred in bringing the merchandise from the point of origin (where the merchandise begins its journey to the United States in Canada or Mexico) to the first port of entry.

The cif (cost, insurance, and freight) value represents the landed value of the merchandise at the first port of arrival in the United States. It is computed by adding “Import Charges” to the “Customs Value” (see definitions above) and therefore excludes U.S. import duties.

## B Estimation at the 3-digit classification level

### B.1 Transport costs estimates: More detailed results

In this section, we report more detailed results for the estimates for international transport costs, by transport mode on a yearly basis, when either additive costs are included in the estimation (Equation (8)) or not (Equation (7)), under our benchmark sectoral classification level (3 digit). Precisely, we complement the results displayed in Table 1 by reporting the estimates of international transport costs for a sample of years over 1974-2013, when the degree of classification retained ( $s$ ) is at the 3-digit classification level. Table 4 reports the results for Air transport. The results for Ocean transport are displayed in Table 5.

### B.2 Variance decomposition exercise

In this section, we provide a variance decomposition exercise on the observed cif-fas price gap. Precisely, we determine the share of the observed variance in the ratio  $\ln(\frac{p_{ik}}{p_{ik}} - 1)$



Table 4: Air: Transport costs estimates, 3-digits (selected years)

Year	1974	1980	1990	2000	2010	2013
<b>Model (A) - With only Ad-Valorem TC (<math>\hat{\tau}^{ice}</math>, in %)</b>						
Mean	6.9	5.4	5.0	3.6	4.2	3.4
Median	5.4	3.8	4.4	2.5	3.4	2.9
<b>Model (B) - With Additive &amp; Ad-Valorem TC</b>						
<i>Ad-valorem term (<math>\hat{\tau}^{adv}</math>, in %)</i>						
Mean	3.6	2.3	2.4	1.7	2.6	1.7
Median	2.7	1.6	1.6	1.2	2.2	1.7
<i>Additive term (<math>\hat{t}^{add}/\tilde{p}</math>, in %)</i>						
Mean	2.6	2.0	1.8	1.3	1.1	1.0
Median	1.1	0.5	0.8	0.5	0.4	0.5
# observations	14955	16118	24958	35027	40279	39351

Notes: TC = Transport Costs. Statistics are obtained weighting each observation by its value in transport (mode-dependent). Additive term expressed in fraction of fas price.

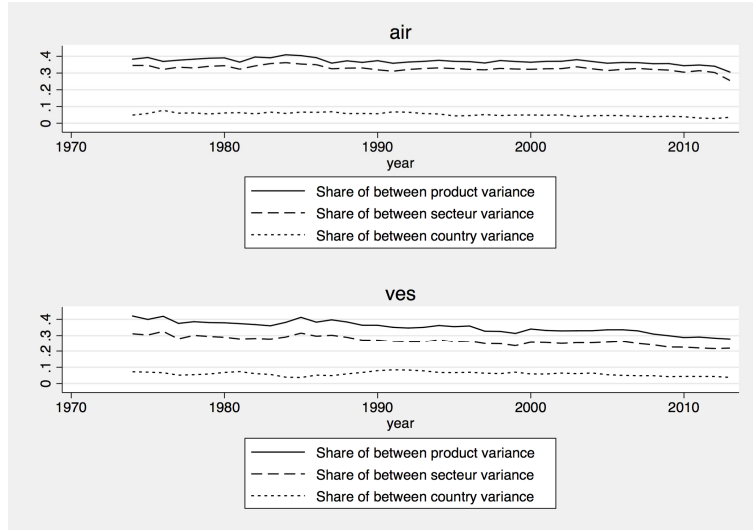
Table 5: Vessel: Transport costs estimates, 3 digit (selected years)

Year	1974	1980	1990	2000	2010	2013
<b>Model (A) - With only Ad-Valorem TC (<math>\hat{\tau}^{ice}</math>, in %)</b>						
Mean	9.8	6.5	5.7	5.1	4.0	3.6
Median	9.6	5.5	4.6	4.9	3.6	3.3
<b>Model (B) - With Additive &amp; Ad-Valorem TC</b>						
<i>Ad-valorem term (<math>\hat{\tau}^{adv}</math>, in %)</i>						
Mean	5.4	3.1	3.3	2.5	1.9	2.2
Median	4.9	2.4	2.8	2.1	1.8	1.8
<i>Additive term (<math>\hat{t}^{add}/\tilde{p}</math>, in %)</i>						
Mean	5.1	3.4	2.7	2.8	2.5	1.5
Median	2.9	2.3	1.7	2.2	1.9	0.8
# observations	19007	17356	28383	36090	37748	38473

Notes: TC = Transport Costs. Statistics are obtained weighting each observation by its value in transport (mode-dependent). Additive term expressed in fraction of fas price.

that comes from *i*) the between-product variance (at the 5-digit level,  $k$ ), *ii*) the between-sector variance (at the 3-digit level,  $s$ ). This gives us an alternative way to ensure the robustness of the estimation results to the degree of classification retained to estimate international transport costs. We also determine the share of the observed variance that can be attributed to the between-country variance. Results are reported in Figure 4.

Figure 4: Variance decomposition (observed cif-fas price gap)



Two interesting results emerge from Figure 4. First, the share of the cif-fas price gap variance that comes from the variance between products (5-digit level) is of same magnitude of order at the variance between sectors at the 3-digit level. Both account for between 30 and 40% of the total variance in Air transport, depending on the years considered. This is also the case for vessel transport, even if the difference between the between-product variance share and the between-sector share is more pronounced (30% for the between-sector vs 40% for the between-product variance at the beginning of the period). This delivers an indirect robustness check to the degree of classification we have retained to estimate international transport costs. Second, the variance of the cif-fas price gap that can be attributed to the product (or sector) dimension is much larger than the between-country variance. This holds throughout the period and for both transport modes. This suggests that what primarily matters in international transport costs is mostly attributable to the product per se, rather than to the country where it comes from. By extension, one can expect a limited role of distance and other country-related variables as determinants of transport costs.

## C Estimation at the 4-digit level

In this section, we report the estimation results when we retain the 4-digit classification level ( $s=4$ -digit).

## C.1 Transport cost estimates

Tables 6 and 7 report the estimates of both models (with and without additive costs) in Air and Ocean transport respectively.

Table 6: Air: Transport costs estimates, Selected years, 4-digit

Year	1974	1981	1989	2001	2009	2013
<b>Model (A) - With only Ad-Valorem TC (<math>\hat{\tau}^{ice}</math>, in %)</b>						
Mean	6.6	5.8	5.2	3.3	3.7	3.2
Median	5.2	4.4	4.1	2.1	2.7	2.6
<b>Model (B) - With Additive &amp; Ad-Valorem TC</b>						
<i>Ad-valorem term (<math>\hat{\tau}^{adv}</math>, in %)</i>						
Mean	3.5	2.6	3.1	1.5	2.1	1.6
Median	2.5	1.7	1.9	1.0	1.7	1.4
<i>Additive term (<math>\hat{t}^{add}/\tilde{p}</math>), in %</i>						
Mean	2.6	2.1	1.7	1.2	1.2	1.0
Median	1.2	0.6	0.6	0.5	0.4	0.4
# observations	14944	16844	25307	35005	38475	39460

Notes: TC = Transport Costs. Statistics are obtained weighting each observation by its value in transport (mode-dependent). Additive term expressed in fraction of fas price.

Table 7: Vessel: Transport costs estimates, Selected years, 4-digit

Year	1974	1981	1989	2001	2009	2013
<b>Model (A) - With only Ad-Valorem TC (<math>\hat{\tau}^{ice}</math>, in %)</b>						
Mean	9.8	6.1	5.	5.1	4.2	3.6
Median	9.4	5.1	4.8	4.5	3.8	3.1
<b>Model (B) - With Additive &amp; Ad-Valorem TC</b>						
<i>Ad-valorem term (<math>\hat{\tau}^{adv}</math>, in %)</i>						
Mean	5.4	3.4	2.8	2.8	2.4	2.1
Median	4.9	3.0	2.4	2.5	2.6	1.8
<i>Additive term (<math>\hat{t}^{add}/\tilde{p}</math>), in %</i>						
Mean	4.6	2.6	3.1	2.4	2.1	1.5
Median	2.9	1.3	1.9	1.5	1.3	0.8
# observations	19196	17916	29387	36677	37643	38820

Notes: TC = Transport Costs. Statistics are obtained weighting each observation by its value in transport (mode-dependent). Additive term expressed in fraction of fas price.

## C.2 Goodness-of-fit tests at the 4-digit level

We now report the goodness-of-fit exercise (conducted by transport mode) at the 4-digit product classification level (for the selected years). The results are reported in Tables 8 (for Air) and 9 (for Vessel).

Table 8: Air: Measures of Goodness-of-fit, 4-digits

	Year					
	1974	1981	1989	2001	2009	2013
<b>R<sup>2</sup></b>						
Model (A)	0.48	0.49	0.50	0.50	0.45	0.35
Model (B)	0.63	0.66	0.65	0.66	0.54	0.45
<b>SER</b>						
Model (A)					0.88	0.93
Model (B)					0.80	0.86
<b>Log-likelihood</b>						
Model (A)	-17505.55	-21813.46	-30960.56	-44067.62	-49375.57	-53197.87
Model (B)	-14895.81	-18589.91	-26553.53	-37297.93	-45747.57	-49899.14
<b>AIC criteria</b>						
Model (A)	36243.10	44966.91	63417.12	89747.24	100317.13	107963.73
Model (B)	31873.63	39495.82	55777.05	77439.85	94059.14	102224.28
<b>Test LL</b>						
2×(ll(UR) -ll(R))	5219.47	6447.09	8814.06	13539.39	7255.99	6597.45
# restrictions	640	698	778	833	824	818
p-value	0.000	0.000	0.000	0.000	0.000	0.000

Notes: Model (A) = with only ad-valorem transport costs. Model (B) = with additive & ad-valorem transport costs. R<sup>2</sup> between the log of predicted ratio and the log of the observed ratio. The number # of restrictions is equal to the number of parameters estimated, i.e., the number of partner countries plus the number of products.

Table 9: Vessel: Measures of Goodness-of-fit, 4-digits

	Year					
	1974	1981	1989	2001	2009	2013
<b>R<sup>2</sup></b>						
Term I only	0.50	0.45	0.47	0.41	0.37	0.35
Terms A & I	0.66	0.62	0.62	0.58	0.51	0.46
<b>SER</b>						
Model (A)					0.79	0.82
Model (B)					0.69	0.75
<b>Log-likelihood</b>						
Model (A)	-16460.10	-16951.61	-26771.44	-39008.34	-43888.90	-47161.62
Model (B)	-12743.65	-13546.92	-21752.77	-33280.96	-39078.86	-43399.22
<b>AIC criteria</b>						
Model (A)	34464.19	35491.21	55272.87	79800.67	89459.80	95987.23
Model (B)	28271.29	29877.84	46595.55	69743.91	81155.73	89692.44
<b>Test LL</b>						
2×(ll(UR) -ll(R))	12385.80	11226.75	17354.65	20113.52	16608.16	12589.59
# restrictions	797	814	881	910	886	874
p-value	0.000	0.000	0.000	0.000	0.000	0.000

Notes: Model (A) = with only ad-valorem transport costs. Model (B) = with additive & ad-valorem transport costs. R<sup>2</sup> between the log of predicted ratio and the log of the observed ratio. The number # of restrictions is equal to the number of parameters estimated, i.e., the number of partner countries plus the number of products.

## D Eliminating the composition effects: More details

In this section, we explain with more details the method employed to eliminate the country- and product- dimensions of the estimated transport cost.

### D.1 More on our methodology

**For the ad-valorem component** Consider first the multiplicative transport cost component. Rewriting Equation (9) by taking the exponential, we get:

$$\hat{\tau}_{ikt} = \exp \left( \delta + \sum_{i \neq \text{AFG}} \alpha_i \mathbb{K}_i + \sum_{k \neq 011} \beta_k \mathbb{K}_k \right) \cdot \exp \left( \sum_{t \neq 1974} \gamma_t \mathbb{K}_t \right) \cdot \exp(\epsilon_{ikt})$$

Based on this equation, we deduce after estimation that:

$$\begin{aligned} \text{For the year 1974} \quad & \hat{\tau}_{is74} = \exp(\delta + \alpha_i + \beta_s), \\ \text{For any year } t > 1974 \quad & \hat{\tau}_{ist} = \exp(\delta + \alpha_i + \beta_s) \times \exp(\gamma_t) \end{aligned}$$

From this, we obtain the following recursive link:  $\hat{\tau}_{ist} = \hat{\tau}_{is74} \exp(\gamma_t)$ . Given that  $\tau > 1$ , we can rewrite to get the percentage change between year 1974 and any year  $t > 1974$ :

$$\Gamma_{ist} = 100 \cdot \frac{\hat{\tau}_{ist} - 1}{\hat{\tau}_{is74} - 1} = 100 \cdot \frac{\hat{\tau}_{is74} \exp(\gamma_t) - 1}{\hat{\tau}_{is74} - 1}$$

As such, the index of transport costs in year  $t$  (relative to the reference year 1974)  $\Gamma_{ist}$  only depends on the cost observed in 1974 and the time trade. At this stage though, it remains specific to a product-origin country pair. Next step is to build the index  $\Gamma_t^{adv}$  such that:

$$\Gamma_t^{adv} = 100 \frac{\bar{\tau}_{1974} \cdot \exp(\gamma_t) - 1}{\bar{\tau}_{1974} - 1}$$

that is, Equation (11) with  $\bar{\tau}_{1974} = \exp(\delta + \sum_i \alpha_i + \sum_k \beta_k)$  the mean (ad-valorem) transport cost in 1974.

**For the additive component** After estimating Equation (10), we can re-build the additive component according to:

$$\begin{aligned} \text{For the year 1974} \quad & \hat{t}_{is74} = \delta + \alpha_i + \beta_s, \\ \text{For any year } t > 1974 \quad & \hat{t}_{ist} = (\delta + \alpha_i + \beta_s) \cdot \exp(\gamma_t) \end{aligned}$$

From this, we deduce the recursive link:  $\hat{t}_{ist} = \hat{t}_{is74} \times \exp(\gamma_t)$ . Given the constraint  $t > 0$ , we then obtain the percentage change from 1974 from:

$$\Gamma_{ist}^{add} = 100 \frac{\hat{t}_{ist}}{\hat{t}_{ik74}} = 100 \exp(\gamma_t)$$

Note that it is independent of the product-origin country pair, we can thus rewrite the time-trend series for the additive transport cost component as:

$$\Gamma_t^{add} = 100 \exp(\gamma_t)$$

that is, Equation (12).

**For the total cost measure** We also build a measure of the “overall” transport costs, that agglomerates our estimates of the two additive and iceberg components. We construct this measure (by transport mode) on both the unfitted series and the “pure” transport cost series (composition effects excluded). Even if obeying to the same logic, we proceed slightly differently for the unfitted and the fitted measures though, as we now explain.

For the unfitted measure, based on Equation (2), we build for each transport mode, the “overall” transport cost as:

$$\hat{tc}_t^{raw} = \hat{\tau}_t^{adv} - 1 + \hat{t}_t$$

where  $\hat{\tau}_t^{adv}$  and  $\hat{t}_t$  have been estimated (by year) as explained in Section 2,  $\hat{\tau}_t^{adv} - 1$  measuring the ad-valorem transport cost component and  $\hat{t}_t$  the additive component, both expressed in percentage of the fas price. For sake of comparison, we transform this “overall” transport cost in an index with basis year 1974, applying a similar formula as above (by transport mode):

$$\Gamma_t^{tc,raw} = 100 \frac{\hat{tc}_t^{raw} - 1}{\hat{tc}_{1974}^{raw} - 1}$$

We apply a slightly different procedure for constructing the fitted measure of total transport cost (i.e., composition effect excluded). In this case, we start directly from the two indices previously obtained (Equations (11) and (12), by transport mode). We build the “overall” transport cost measure as a weighted sum of the two indices, using the relative weight of the additive cost component in total cost in 1974,  $\omega_{air} = 0.423$  and  $\omega_{ocean} = 0.482$  (obtained from our estimates in Section 3, see Tables 4 and 5), according to:

$$\Gamma_t^{tc,pure} = \omega_x \Gamma_t^{add} + (1 - \omega_x) \Gamma_t^{adv}$$

with  $x = \{air, vessel\}$ .

## D.2 Comparing with Hummels (2007)

In this section, we investigate the difference of results with Hummels (2007) regarding the importance of the composition effects in characterizing the time trends of international transport costs. In order to do so, we start from the empirical specification implemented by Hummels (2007) (also making use of Hummels’ Stata codes provided on his webpage<sup>31</sup>), to better identify the precise points of difference between our estimation strategies.

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<sup>31</sup><http://www.krannert.purdue.edu/faculty/hummelsd/research/jep-transport-cost-data.php>

Let us start from Hummels' (2007) quotation (p. 146) according to which (for air), the “*unadjusted measure of ad valorem air shipping costs [is] the aggregate expenditures on air shipping divided by the value of airborne imports*”. From this, we get the “raw” ad-valorem measure of transport costs as the ratio between the imported total value and the exported total value  $((p_{ikt} - \tilde{p}_{ikt})q_{ikt}/\tilde{p}_{ikt}q_{ikt})$ , the mean yearly value being obtained by weighting each flow by its value in total trade flows (ie, yielding the observed aggregate value of  $\tau_t$  for air).

Consider now the “fitted ad-valorem rate”. Hummels (2007) uses “*a regression in which the dependent variable is the ad-valorem air freight cost in logs for commodity  $k$  shipped from exporter  $i$ <sup>32</sup> at time  $t$ . The independent variables include a separate intercept for each exporter-commodity shipped, the weight/value ratio in logs for each shipment, and year dummy variables*”. With the value of the shipment equal to  $\tilde{p}_{ikt}q_{ikt}$ , and denoting the air freight cost as  $TC_{ikt}$ , we can formulate the above sentence according to the following equation (suppressing the transport mode index to alleviate notation):

$$\begin{aligned} \ln TC_{ikt} &= \delta + \beta \ln \frac{q_{ikt}}{\tilde{p}_{ikt}q_{ikt}} + \sum_{i,k} \alpha_{ik} \mathcal{K}_{ik} + \sum_t \gamma_t \mathcal{K}_t + \epsilon_{ikt} \\ \Leftrightarrow \quad \ln TC_{ikt} &= \delta + \beta \ln \frac{1}{\tilde{p}_{ikt}} + \sum_{i,k} \alpha_{ik} \mathcal{K}_{ik} + \sum_t \gamma_t \mathcal{K}_t + \epsilon_{ikt} \end{aligned} \quad (13)$$

where  $TC_{ikt}$  is measured by the ratio between (air) charges, i.e.  $(p_{ikt} - \tilde{p}_{ikt})q_{ikt}^{fas}$  and the value of the shipment, i.e.  $\tilde{p}_{ikt}q_{ikt}^{fas}$ , or equivalently :  $TC_{ikt} = \frac{p_{ikt} - \tilde{p}_{ikt}}{\tilde{p}_{ikt}}$ .

After estimating Equation (13), Hummels (2007) uses the predicted value of the regression, denoted  $\widehat{TC}_{ikt}$ , to obtain the unweighed average in the product/origin country dimension  $i, k$ , that is  $\widehat{TC}_t$ , to be compared to the unfitted ad-valorem rate  $TC_t$  (by transport mode).

What are the main differences with our estimation strategy? Five points may be underlined. First, Hummels (2007) obtains the fitted ad-valorem rate in one step (considering the observed export-import price gap on the left-hand side of Equation (13)), while we use our two-step approach to extract the fitted transport cost (ie, composition effect excluded) from the (already estimated) unfitted rate. However, this is a slight difference, as in both cases it ultimately amounts taking the predicted value of Equation (13) (which eliminates the changes specific to the origin country/product/year triplet).

A second minor difference is that we separate the country-product fixed effects ( $\sum_{i,k} \alpha_{ik} \mathcal{K}_{ik}$  in Equation (13)) in two separate components (origin country and product dimensions). As discussed in Section ??, this is constrained by the number of fixed effects to estimate. However, we do not view this as the major cause of difference between our two methods, as it can be inferred from the robustness analysis on this point in Section ??.

Third, in contrast to us, Hummels (2007) does not purge its measure of the fitted ad-

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<sup>32</sup>To be consistent with our notations, we change the country subscript from  $j$  (Hummels' (2007) terminology) to  $i$  (our terminology).

valorem rate by the country-sector fixed effects. This is not likely to make a substantial difference though, as these fixed effects are by nature constant over time. Accordingly, they only play as a scale effect as the estimate is in log. Fourth, we differ in the weighting scheme retained to obtain the yearly value of the fitted transport cost (in the terms of Hummels' (2007) method, the switch from  $\widehat{TC}_{ikt}$  to  $\widehat{TC}_t$ , Equations (11) and (12) in our case). Hummels (2007) takes the unweighed average value over the  $i, k$  dimension, which implicitly attributes a weight equal to 1 to each flow. We proceed differently, as we weight each flow by its relative value on total trade flows observed in 1974. This choice is made for two reasons. First, this weighting scheme does not overweight the small flows in value. Second, considering the 1974 weighting scheme makes sense as starting point of our time trend analysis. However, we ensure that our results are not sensitive to an alternative weighting scheme, by building the average fitted transport costs rate as in Hummels (2007) (Results available upon request to the authors).

One last difference remains to be commented, which relies on the way the additive component of international transport costs is treated. As we show below, it turns out to be key in accounting for the difference of results with Hummels (2007). Coming back to Equation (13), it can be shown that it encompasses the two extreme cases of only ad-valorem costs ( $\beta = 0$ ) and only additive costs ( $\beta = 1$ ), as also pointed out in Hummels and Skiba (2004). To see it clearly, rewrite Equation (13) in a simpler form as:

$$\ln TC_{ikt} \equiv \ln \left( \frac{p_{ikt} - \tilde{p}_{ikt}}{\tilde{p}_{ikt}} \right) = \Delta_{ikt} - \beta \ln \tilde{p}_{ikt}$$

with  $\Delta_{ikt} \equiv \sum_{i,k} \alpha_{ik} \mathbb{K}_{ik} + \sum_t \gamma_t \mathbb{K}_t$  agglomerates the various fixed effects for reading clarity.

Under the first polar case with  $\beta = 1$ , it becomes:

$$\begin{aligned} \ln \left( \frac{p_{ikt} - \tilde{p}_{ikt}}{\tilde{p}_{ikt}} \right) &= \Delta_{ikt} - \ln \tilde{p}_{ikt} \\ \Leftrightarrow \ln(p_{ikt} - \tilde{p}_{ikt}) &= \Delta_{ikt} \end{aligned}$$

Equivalently, we can write:

$$\begin{aligned} p_{ikt} &= \tilde{p}_{ikt} + \exp(\Delta_{ikt}) \\ \Leftrightarrow p_{ikt} &= \tilde{p}_{ikt} + t_{ikt} \end{aligned}$$

with  $t_{ikt}$  appropriately defined. This exactly corresponds to the case of additive costs only.



In the second polar case with  $\beta = 0$ , Equation (13) becomes:

$$\begin{aligned} \ln \left( \frac{p_{ikt} - \tilde{p}_{ikt}}{\tilde{p}_{ikt}} \right) &= \Delta_{ikt} \\ \Leftrightarrow \ln \left( \frac{p_{ikt}}{\tilde{p}_{ikt}} - 1 \right) &= \Delta_{ikt} \\ \Leftrightarrow \frac{p_{ikt}}{\tilde{p}_{ikt}} &= \exp(\Delta_{ikt}) + 1 \end{aligned}$$

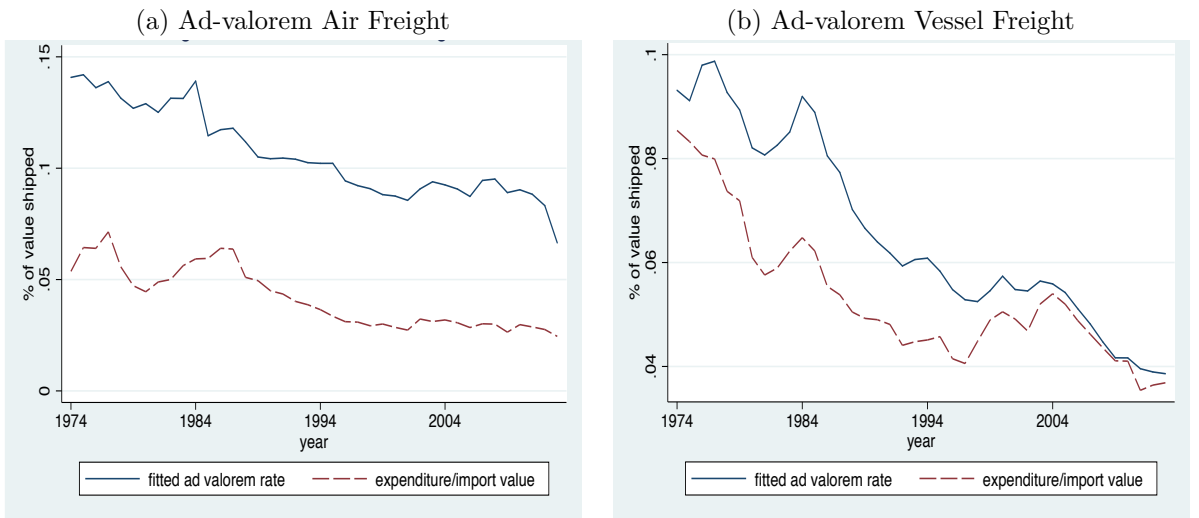
that is,

$$p_{ikt} = \tau_{ikt} \tilde{p}_{ikt}$$

with  $\tau_{ikt}$  appropriately defined. This exactly corresponds to the case of ad-valorem transport costs only.

As noted by Hummels and Skiba (2004),  $0 < \beta < 1$  represents the elasticity of freight costs to the export prices, increasing with the relative weight of the additive component in international transport costs. By estimating Equation (13) with a constant  $\beta$ , Hummels (2007) assumes that the share of additive costs does not vary over time, country partner or product. This is an important difference with our method, as we measure transport costs by explicitly allowing for an additive component that varies in the three dimensions (ie, somehow allowing for a varying  $\beta$  across time, country partner and product). To establish this point clearly, we replicate the method adopted by Hummels (2007) exposed above on our database (which is the same as his until 2004). The results are reported in Figure 5. The dotted line labeled “expenditure/import value” represents the unfitted measure of transport costs ( $TC_t$  in the above terminology) and the plain line labeled “fitted ad-valorem rate” is the measure of transport costs composition effects excluded ( $\widehat{TC}_t$ ).

Figure 5: Characterizing the time trends: Applying Hummel’s (2007) method



As expected, these figures are strictly identical for pre-2004 years to Figures 5 and 6 in Hummels (2007). More importantly, these results stand in sharp contrast with the

ones obtained with our methodology and reported in Figure 3. Applying Hummels' (2007) method, we obtain that the composition effects tend to compensate the decrease in transport costs in both air and ocean shipping (unsurprisingly in accordance with Hummels' (2007) results, see his Figures 5 (for Air) and 6 (for Ocean)). This result is overturned when we allow for more flexibility in the role of the additive component, as depicted in Figure 3. Complementing the findings of Section 3, these results point out the importance of integrating the additive dimension of international transport costs, here in view of characterizing their time trends.