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 relied on modelling trade costs as an ad-valorem tax equivalent. However, many common empirical facts support the existence of additive costs. This paper provides a quantitative assessment of the size and the importance of the additive component in international transport costs, measured as the cif-fab price gap, using US imports flows over 1974-2013. We thus find that additive transport costs are not negligible, with mean values over the period of 1.8% and 2.9% of the export price in air and maritime transport respectively. Further, taking additive costs into account significantly improves the fit of the modelling of transport costs. We also use the time dimension of our data to characterize the patterns of transport costs over time. After correcting for composition effects, we find that international transport costs have decreased by 50% in air transport and 60% in maritime transport over the period, and of same order of magnitude for both additive and iceberg components. These results therefore confirm the importance of the additive component in accounting for international transport costs.

pas tres sexy la fin. Dire tout de meme que ca reste non negligeable? Avec la valeur moyenne sur 2010-2013 par ex, pour additif et pour multiplicative.

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1 Introduction

Trade costs are central in 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), trade cost declines explain 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 starting in 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 (e.g. 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 into 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. Behar and Venables (2011) obtain that the elasticity of trade with respect to freight costs is sizeable, by around -3, suggesting 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 relied on modelling 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[1]). However, many common empirical facts support the existence of additive costs. 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, as the literature has long emphasized its role in shaping the pattern of trade flows. The Alchian and Allen conjecture (Alchian and Allen, 1964), that points out that the relative price of two varieties of some good will depend on the level of trade costs, does rely on the existence of additive costs: The relative demand for more expensive/higher quality product goods should increase with trade cost ("shipping the good apples out"). Lashkaripour (2016) challenges this view. He finds supporting evidence for the *ad-valorem* assumption by taking into account the fact that

[1]Rigourously speaking, the "iceberg cost" includes the ad-valorem costs and the fact that the 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 made in the literature.

more expensive goods are systematically heavier and hence more costly to transport. One can yet be concerned by the generality of this result. By nature, his 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 costs. Based on a firm-product-level database of French exporters, Martin (2012) finds that firms charge higher fas unit values on 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 fas export prices by 80-141 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.[2] 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.[3] 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. In this respect, the paper is related to the literature that challenges the dominant role of iceberg costs in international trade.[4] We quantitatively assess the size and the importance of the additive component in international transport costs, that we measure as the difference between the import and the export prices, based on the US Imports flows over 1974-2013.

[2]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.

[3]The one exception being Irarrazabal *et al.* (2015), upon which we come back later.

[4]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.

Therefore, we focus only on a subset of trade costs. Besides, in terms of transport costs *per se*, our measure based on the gap between export and import prices 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 (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...). However, 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 a bunch of 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 origin, and allows for a wide time and geographical coverage, while limiting the measurement errors coming from strategies inferring trade costs. Therefore, we strongly believe they may deliver useful and reliable insights on the structure of international trade costs.

Closely related to our paper is the work by Irarrazabal *et al.* (2015), which develops a structural framework for inferring additive trade costs from firm-level trade data. Based on Norwegian exports in 2004, they find that additive costs are about 14% of the median consumer price. Our paper complements their findings in many respects. While they study trade costs in general, our database implies that we focus on international transport costs. Similarly to them, our various results emphasize the important role of the additive component of international transport costs. Further, our empirical analysis allows us to provide a quantitative measure of the levels of both the iceberg and the additive trade costs. Last, 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. By exploiting the time coverage of our database, our paper is also related to the international trade literature that studies the patterns of trade costs over time, such as Hummels (2007) and Behar and Venables (2011). We also share in common with these papers to investigate the time trends of transport costs by transport mode (i.e., air or sea). Many argue that transport costs have substantially decreased with technological advance in transportation, infrastructure development and new communication technologies (seeLafourcade 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) shows that the bulk of price declines in transportation comes from air transport, where average cost per ton-kilometer shipped dropped by 92% between 1955 and 2004. Concerning ocean shipping, which represents the major part of world trade, decline in trade prices are much less obvious, a conclusion in accordance with the studies reviewed by Behar and Venables (2011). Our paper contributes to this debate. In particular, we show the importance of taking into account the additive component in characterizing the time trends of international transport costs. Our findings can be summarized in three main points.

First, our theoretically agnostic approach provides a fairly simple 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 ocean transport respectively, whereas the additive component amounts to 1.8% and 2.9%. To our best knowledge, our paper is the first to provide such an extensive quantitative measure of both ad-valorem and additive costs in total transport costs.[5] This represents a valuable insight for calibrating related models.

mettre une phrase pour dire qu'on confirme la littérature sur le role des additifs, mais de maniere differente. Hummels et Skiba sur des donnes de 1994, on va beaucoup plus loin qu'eux dans cette voie.

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 estimate for ad-valorem is 5% for air and 6% for vessel, while unbiased estimate is 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. As pointed out by Hummels (2007), we confirm the importance of the composition effects by country of origin and by product in shaping the patterns of transportation costs over time. In contrast to his work though, our empirical analysis allows for a more flexible estimation of the share between the additive and the ad-valorem components of transport costs. Precisely, we allow it to change over time and across country partners and products, while Hummels (2007) imposes it to be constant in these three dimensions. After excluding the composition effects, we find that all types of transport costs have been roughly constant from 1974 to 1984 and then steadily decreased by 40% over the period 1984-2013. Further, our results point out an important bias in the time trends of transport costs when additive costs are omitted. While transport costs seem to exhibit a larger decrease in air than in sea transport between 1985 and 2005 when only iceberg costs are modeled, this difference vanishes when additive costs are taken into account. These results therefore confirm 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. Sections 3 and 4 report our results. In Section 3, we characterize 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 in each component of transport costs (by transport

[5] Given their database and their methodology, 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 ($\bar{\widetilde{p}}_{ik}$). By contrast, our estimation strategy enables us to uncover both values of the ad-valorem and the additive costs τ_{ik} and t_{ik} separately, in terms of the country-product export price $\widetilde{p}_{ik}$.

mode) over the period 1974-2013. Section 6 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,[6] 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.[7] 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 therefore with 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).

It is worth acknowledging that using this dataset encounters some 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, it is true that using this dataset embraces a partial view of international transport barriers.

Yet, we believe that our analysis delivers valuable insights on this topic. Indeed, using this dataset has (at least) three main advantages. First, this dataset delivers a strong statistical reliability arising from a single, trustworthy, customs origin. Based 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. In addition, the database reports information regarding freight, insurance and handling expenditures by transportation mode (ocean (or "vessel") and air). The first will be crucial to compute transport costs (see below), the second will allow to enlighten substantial differences in the dynamics of transport costs across

[6] More information available at: `http://www.census.gov/foreign-trade/reference/products/catalog/fl_imp.txt`

[7] 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.

transportation mode. Second, using this dataset allows us to have the import price of the good, next to the export price. This is highly valuable, as we can estimate both the *levels* of the iceberg costs and of the additive costs. This strongly differentiates us from Irarrazabal *et al.* (2015), who can only estimate the ratio of additive costs as a share of the median total consumer price. 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 differentiates from his work in two main respects. First, we extend the time coverage to the more recent period up to 2013, while Hummels (2007) stops in 2004. As we show in Section 4, covering the time period over the recent years delivers interesting insights regarding the trends in air shipping costs. Second, we study the time trends of transport costs by disentangling the additive from the iceberg components. This proves to be important in the characterization of transport costs changes over time, in particular in air transport.

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.[8] 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 estimates over time 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 $\widetilde{p}_{isk}$ (export, or fas price), given both per-kg (t) and ad-valorem (τ) transport costs, according to:

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

As usual in the literature, the iceberg trade costs are denoted τ (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. Transforming the above equation (1) as ratio, we thus get the following equation at the root of our estimation:[9]

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

[8]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. We thus 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.

[9]We skip the year and transport-mode dimensions in the notations for reading convenience.

Estimation Strategy We follow Irarrazabal *et al.* (2015) by considering that *1)* both ad-valorem and additive costs are separable between the origin country (i) and the product (k) dimensions, and *2)* this separability is in a multiplicative way for the former and an additive way for the latter. In other words, τ_{ik} and t_{ik} from Equation (2) are written as:[10]

$$\tau_{ik} = \tau_i \times \tau_k \tag{3}$$
$$t_{ik} = t_i + t_k \tag{4}$$

As a result, our underlying theoretical 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 estimation 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 ϵ_{ik} follows an normal law centered on 0. Considered in logs, the above equation becomes:

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

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.[11] 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). Put it differently, this amounts making the additional assumption, that all products k in a 3-digit sector s share the same structure of costs.[12] This drives us to estimate a modified version of Equation (5), specified as:

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

[10] 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 $t_i + t_k \simeq (1 + t_i) \times (1 + t_k) - 1$.

[11] 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.

[12] We ensure the robustness of our estimation results to this assumption in two ways. First, we conduct the estimations at the 4-digit level for some selected years. As reported in Appendix C, the results are not substantially affected. Second, we provide a decomposition variance exercise on the observed cif-fas price. As reported in Appendix 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.

where τ_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 ϵ_{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. Put it differently, what traditional models of international trade lose by ignoring additive costs? A natural way to answer this question is to perform estimations of Equation (6) constraining additive costs t 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 dimensions of additive and iceberg (Equation (8)):

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

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

One may be concerned that the specification of Equations (7) or (8) might be subject to endogeneity bias, as the price set be the exporter may vary depending on the transport cost burden. Notably based on the pricing-to-market behavior of firms (see Krugman, 1987), we cannot exclude that the export price set by the firm ($\widetilde{p}_{ik}$) 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, 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 ocean transport (that is beyond our scope of analysis). Otherwise stated, conditional to an export price and a transport mode, the gap between 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-built a measure of each component $\widehat{\tau}_{is}^{adv} = \widehat{\tau}_i \times \widehat{\tau}_{s(k)}$ and $\widehat{t}_{is} = \widehat{t}_i + \widehat{t}_{s(k)}$, that is country-sector specific, by year and transport mode. When assuming iceberg costs only (Equation (7)), we proceed similarly to get $\widehat{\tau}_{is}^{ice} = \widehat{\tau}_i \times \widehat{\tau}_s$.[13,14] Similarly as Irarrazabal *et al.* (2015), we take the average over the sector-

[13]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.

[14]One may 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

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)* $\widehat{\tau}^{ice}$, *b)* $\widehat{\tau}^{adv}$ and $\widehat{t}$, 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 evaluate the importance of the additive component of in overall transport costs through the means of 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 (ad-valorem estimated alone, estimated along with additive costs and the additive component), 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.[15,16]

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 is no surprise at all: once again, our key variable is by nature bounded to 0; therefore, outliers can only be positive, pushing the mean up compared to the median. Besides, one can also note that estimated total costs are also systematically higher than observed costs by 0.5 to 1 percentage point. This is due to the fact that observed data are *de facto* trade-weighted (i.e., by the weight of each good among total trade), while

the estimated equation is written according to: $\ln\left(\frac{p_{ik}}{\widetilde{p}_{ik}} - 1\right) = \ln\left(\frac{t_i + t_{s(k)}}{\widetilde{p}_{ik}}\right) + \epsilon_{ik}^{add}$. 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. For sake of space saving, the results of this third model are not reported in the paper. Of course, they are available upon request to the authors.

[15] 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.

[16] 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
With only Ad-Valorem Trade Costs ($\widehat{\tau}^{ice}$, in %)				
Mean	5.8	5.1	6.0	4.9
Median	5.1	4.2	5.2	3.7
With Additive & Ad-Valorem Trade Costs				
Ad-valorem term ($\widehat{\tau}^{adv}$, *in %*)				
Mean	3.2	2.5	3.3	2.4
Median	2.8	1.8	2.8	1.6
Additive term ($\widehat{t}^{add}/\widetilde{p}$, *in %*)				
Mean	2.9	1.8	2.8	1.9
Median	1.9	0.7	1.7	0.8
Data ($p/\widetilde{p}$, in %)				
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.

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-linearizations. 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 ($\ln\left(\frac{p_{ik}}{\widetilde{p}_{ik}}-1\right)$), which does not necessarily imply equality between values. Descriptive statistics showing that it is indeed the case available upon request to the authors.

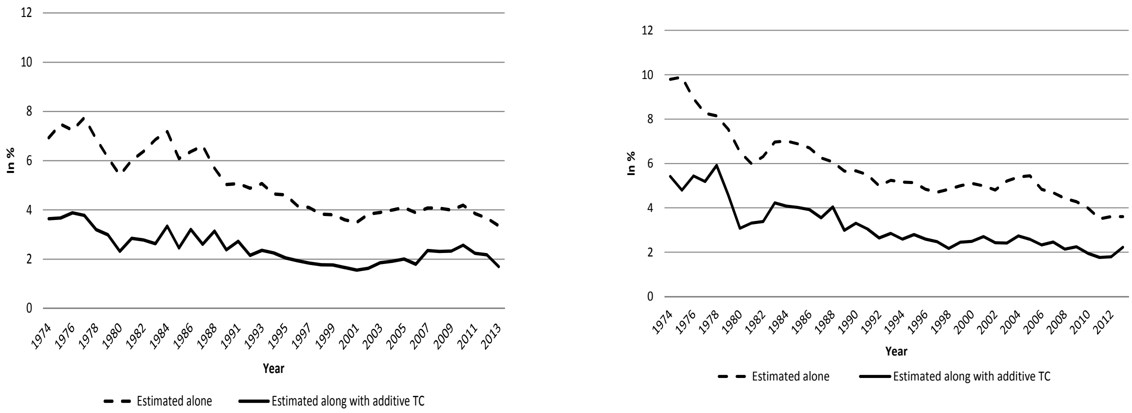
Coming now to interpretation, Table 1 shows the magnitude of overall transport costs is sizeable. Over 1974-2013, they correspond to a mean increase of the export price by 5.8% for ocean shipping, and by 5.1% for air shipping. Furthermore, when decomposing transport costs into an additive and an ad-valorem 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 - and ad-valorem ones being equal to 3.2%. These values are respectively equal to 1.8% and 2.5% for air transport. 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 analysis 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.

From Figure 1, we can infer that the sizeable magnitude of additive costs also holds on a yearly basis. Further, Figure 1 reports that for Air, the size of the bias seems to decrease

Figure 1: Ad-valorem Costs (Yearly mean value, 3 digits)

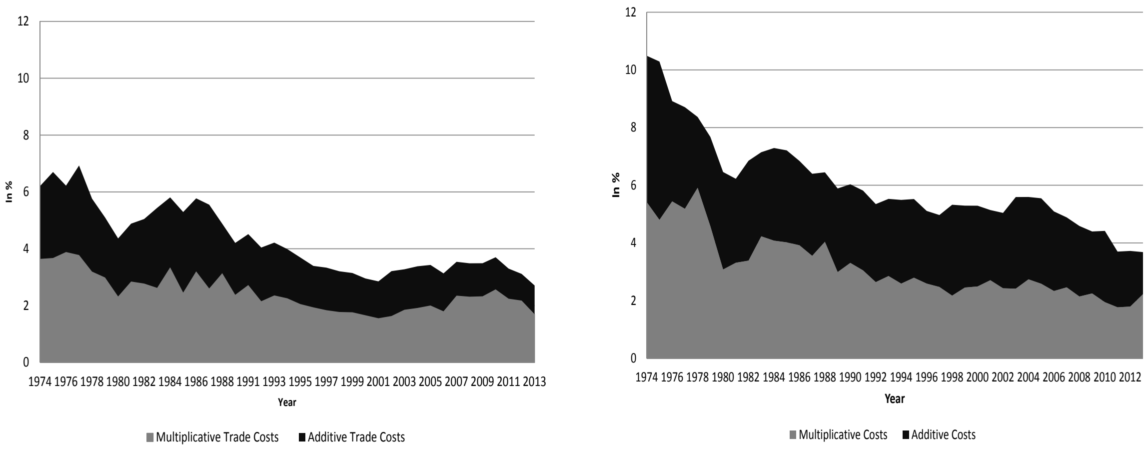
(a) Air (b) Vessel



over time, while it appears rather stationary for ocean shipping. Put it differently, this suggests that the share of the additive component in total transport costs has decreased over time for air transport. 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)

(a) Air (b) Vessel



The overall trend pictured in these estimates is in line with the findings by Hummels (1999), who point that the overall transport cost for the United States declined from 6 percent to 4 percent between 1974 and 1996. For the same years, our own results point to a total decrease from 6.9 to 4.2% on average for air transport, and from 9.8% to 4.8% for ocean transport.[17] Once again, the fact that our estimates are on average higher

[17]One may be puzzled for by the high magnitude of estimates for the beginning of the period (say, until

than those by Hummels (1999) should not be a surprise, since ours are simple averages, whereas Hummels (1999)'s are trade-weighted. But the fact that trends are very close are comforting. It appears therefore that the magnitude of transport costs is higher for ocean shipping than for air transport.

Besides, we go beyond 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), for all years throughout the period. 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. We go on investigating this result further in the next subsection.[18]

Before, we check how our estimates of additive costs compare to those of Irarrazabal *et al.* (2015), which provide the most recent evidence on that matter. Based on Norwegian firm-level trade data for 2004, Irarrazabal *et al.* (2015) find that additive costs are on average 14% of the median price. Expressed in our own terminology, this means they find that $\frac{t/\tau}{\widetilde{p}} = 14\%$. Let us define the ratio of additive costs over total costs as $\frac{t}{\tau\widetilde{p}+t}$, and divide both numerators and denominators by $\tau\widetilde{p}$. We get: $\frac{t}{\tau\widetilde{p}+t} = \frac{t/\tau\widetilde{p}}{1+t/\tau\widetilde{p}}$. Plugging Irarrazabal *et al.* (2015) result gives 0,14/1+0,14= 12,5%. Additive trade costs represents 12.5% of total trade costs. Based on Anderson and Van Wincoop (2004), we know that 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. Given that in 2004, our estimates for additive (multiplicative) transport costs is 2.9% (2.7%) for Vessel, the same reasoning as before leads to 2.9/(2.7+2.9)*11/74 = 7.7% of total trade costs, that is 62% (7.7/12.5=62%) of Irarrazabal *et al.* (2015)'s estimates. For Air transportation, our estimates for additive (multiplicative) transport costs is 1.5% (1.9%), and the same computation brings that additive costs represent 6.6% of total trade costs, that is 53% of Irarrazabal *et al.* (2015)'s estimates. In other words, we find that additive transport costs represent between half and two thirds of the total additive trade costs, which seems totally consistent with the magnitudes reported by e.g. Anderson and Van Wincoop (2004).

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.[19] This drives us

1980) 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 freight rates.

[18] Figure 2 also delivers interesting results with respect to the time trends of transport costs. We come back to this aspect in Section 4.

[19] 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,

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. Smaller values are better because 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.[20] 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 an additive term, i.e. Equation (8) and the Restricted one (*R*, i.e. Equation (7)). The null 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.[21]

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

Year	1974	1980	1990	2000	2010	2013	Mean stat
R^2							
Term I only	0.30	0.27	0.25	0.32	0.42	0.34	0.31
Terms A & I	0.59	0.65	0.63	0.64	0.51	0.46	0.60
SER							
Term I only	0.79	0.86	0.81	0.84	0.86	0.92	0.85
Terms A & I	0.67	0.71	0.67	0.70	0.79	0.85	0.73
AIC criteria							
Term I only	35674.98	41170.98	60715.58	87492.55	102297.66	88191.87	70498.1
Terms A & I	31387.29	35738.39	52098.91	74954.88	95887.05	80873.72	62285.0
Log-likelihood							
Term I only	-17530.5	-20253.5	-29977.8	-43341.3	-50746.8	-43692.9	-34888.6
Terms A & I	-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: 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

a standard metric like R^2 remains informative on the quality of adjustment.

[20] Precisely, the AIC stat is equal to 2 $\times$ number of parameters $-$ 2 $\times$ Likelihood.

[21] Due to our time coverage, we do not report the results for all years (at the 3-digit level). The results for all years are available upon request to the authors.

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

Year	1974	1980	1990	2000	2010	2013	Mean stat
R^2							
Term I only	0.450	0.415	0.456	0.401	0.350	0.339	0.39
Terms A & I	0.612	0.575	0.590	0.571	0.491	0.462	0.56
SER							
Term I only	0.58	0.62	0.59	0.65	0.74	0.76	0.66
Terms A & I	0.48	0.53	0.51	0.55	0.66	0.68	0.57
AIC criteria							
Term I only	33328.8	33010.3	51142.6	71365.9	84789.9	88191.9	57848.6
Terms A & I	27331.5	28067.3	43664.7	60475.9	76161.3	80873.7	49682.3
Log-likelihood							
Term I only	-16287.4	-16129.1	-25169.3	-35263.9	-41998.9	-43692.9	-28534.3
Terms A & I	-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: 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.

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 **??**, Tables 8 and 9. If anything, the quality of fitting appears slightly higher when estimations are based on the 4-digit classification. This is especially true for the model restricting trade 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 with 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

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, which displays the respective shares of additive and iceberg components in transport costs over time by transport mode. Let us consider first the trend in total transport costs (the upper line in Figure 2). Two main comments can be made. First, both air and ocean 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).[22] Second, the

[22]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

decrease appears more pronounced for sea than air transportation. These results are consistent with Hummels (2007).

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 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 argued by Hummels (2007), it is hence necessary to eliminate the composition effects of trade flows to isolate the evolution of "pure" international transport costs, i.e. per product- and per partner- transport costs.

If we share this view with Hummels (2007), our strategy for eliminating composition effects differs from his in two main respects. First, we provide a broader characterization of the time trends in transport costs, by identifying the trend patterns of the "pure" transport costs" (composition effects excluded) for the two additive and ad-valorem dimensions. Our empirical analysis indeed allows for a flexible estimation of the share between the additive and the ad-valorem components of transport costs, over time/product/country partner.[23] Accordingly, our estimation strategy allows for an explicit decomposition of the additive cost component taking these three dimensions into account. By contrast, in its decomposition exercise to characterize the time trend in transport costs, Hummels (2007) does not take into account the changes in their additive dimension, attributing this to a change in the composition of the bundle over time (per country-commodity).[24] 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 "pure" 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 "pure" transport costs have changed over time, composition effects excluded, and to compare them to the unfitted ones.[25]

Our second difference with Hummels (2007) relates to the way we characterize the evolution of the "pure" transport costs over time. Hummels (2007) captures the trend evolution of by the yearly dummy. Rather, we measure how these costs have changed

Est-ce qu'on peut faire a sans prsenter l'quation d'Hummels pour de vrai ?

1980 is -2% for mean air transport costs and -1.6% for mean ocean 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.

[23]The empirical specification of Hummels (2007), as in Hummels and Skiba (2004), assumes a constant share of additive transport costs over time, product and country partner. In Hummels and Skiba (2004), this shows up through the fact that the elasticity of freight costs to prices β is estimated as a constant (with $0 < \beta < 1$, the lower β the larger the additive cost dimension). By contrast, our estimation strategy allows for a varying β across time, country partner and product.

[24]See Hummels (2007), p. 146.

[25]Notice that these "unfitted" total transport costs are virtually the same as those reported in Figure 2, but reported in another perspective (basis 100 in year 1974).

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). This notably enables us to obtain measures of transport costs that are easily comparable between transport modes and transport costs components.

To do this, we estimate the following equations for the estimated ad-valorem component using OLS:

$$\ln(\widehat{\tau}_{ikt}) = \delta + \underbrace{\sum_{i\neq \text{ARG}} \alpha_i.\mathbb{1}_i}_{(a)} + \underbrace{\sum_{s(k)\neq 011} \beta_{s(k)}.\mathbb{1}_{s(k)}}_{(b)} + \underbrace{\sum_{t\neq 1974} \gamma_t.\mathbb{1}_t}_{(c)} + \epsilon_{ikt} \tag{9}$$

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:[26]

$$\ln(\widehat{t}_{ikt}) = \ln\left(\delta + \underbrace{\sum_{i\neq \text{ARG}} \alpha_i.\mathbb{1}_i}_{(a)} + \underbrace{\sum_{s(k)} \beta_{s(k)}.\mathbb{1}_{s(k)}}_{(b)}\right) + \underbrace{\sum_{t\neq 1974} \gamma_t.\mathbb{1}_t}_{(c)} + \epsilon_{ikt} \tag{10}$$

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 "pure 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.[27] Both equations are estimated using by transport mode.

In this exercise, we are interested in isolating the change in the time dimension of the each transport cost component. From the estimation of Equation (9), we built the variable Γ_t^{adv}, for each year $t \geq 1974$, according to:[28]

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

with $\bar{\tau}_{1974} = \exp(\delta + \sum_i \alpha_i + \sum_s \beta_s)$ the mean transport cost or the mean multiplicative transport cost in 1974.

As for the additive cost, we built the variable Γ_t^{add}, the reference year being 1974 (ie, with $\gamma_{1974} = 0$) according to:

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

[26]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 γ_t differs from one estimation to the other).

[27]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.

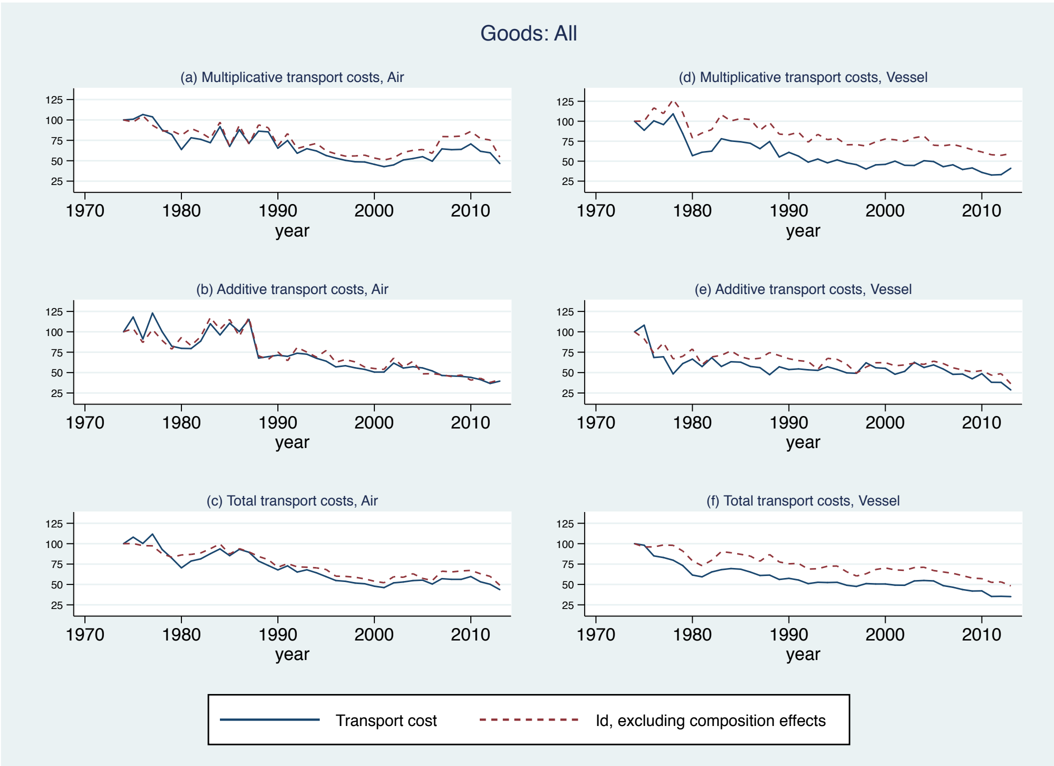
[28]See details in Appendix D.

As a result, the three series (for Γ_t^{adv} and Γ_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 "pure" estimated transport costs (composition effects excluded, see Appendix D).

Figure 3 reports the results. 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)



We also proceed to the same analysis at a more disaggregated level, by distinguishing the trade flows for primary goods and manufactured goods.[29] The evolution in transport costs over time, by transport mode (overall transport costs and composition effects excluded) are reported in 4 for the manufacturing sector, and in Figure 5 for the primary goods.

Consider first the time trends in transport costs at the aggregate level (Figure 3). Three main results emerge. First, we do not find evidence of a significant difference between the raw transport costs and the "pure" transport costs in Air transport, for both the additive and ad-valorem components (Figure 3, left panels). Air transport costs were

[29]See more details in Appendix D. We also run the same exercise at the 1-digit level. For sake of conciseness, these results are not reported. They are available upon request to the authors.

Figure 4: Transport costs (with and without composition effects), Manufacturing

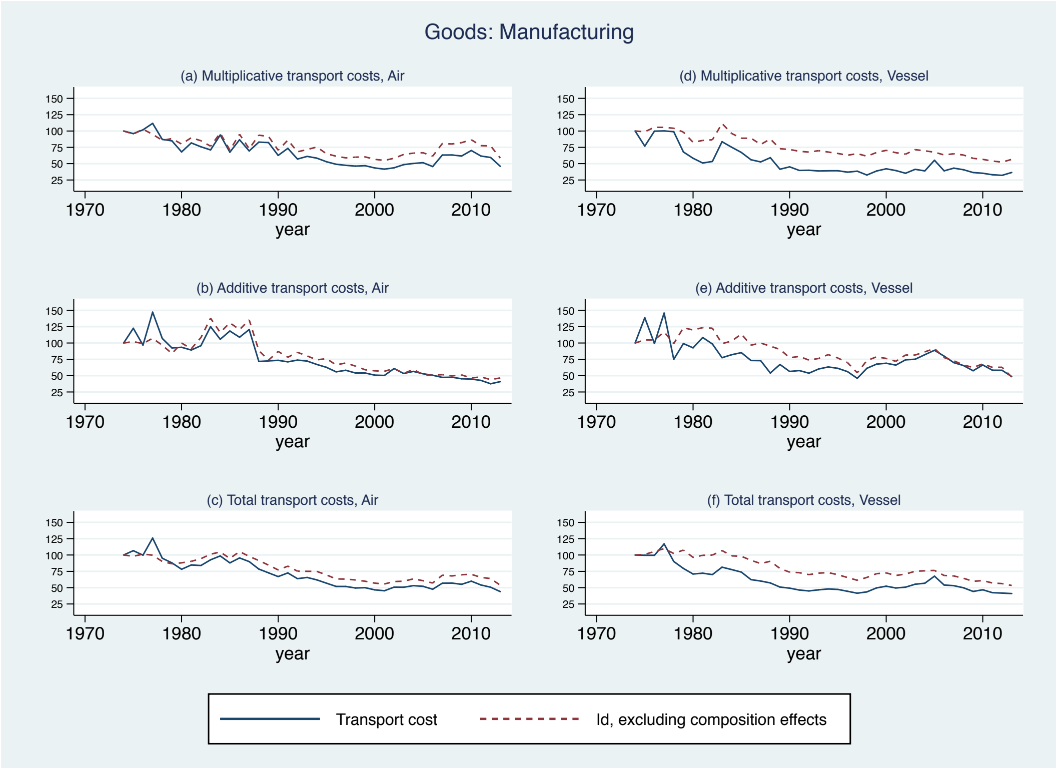
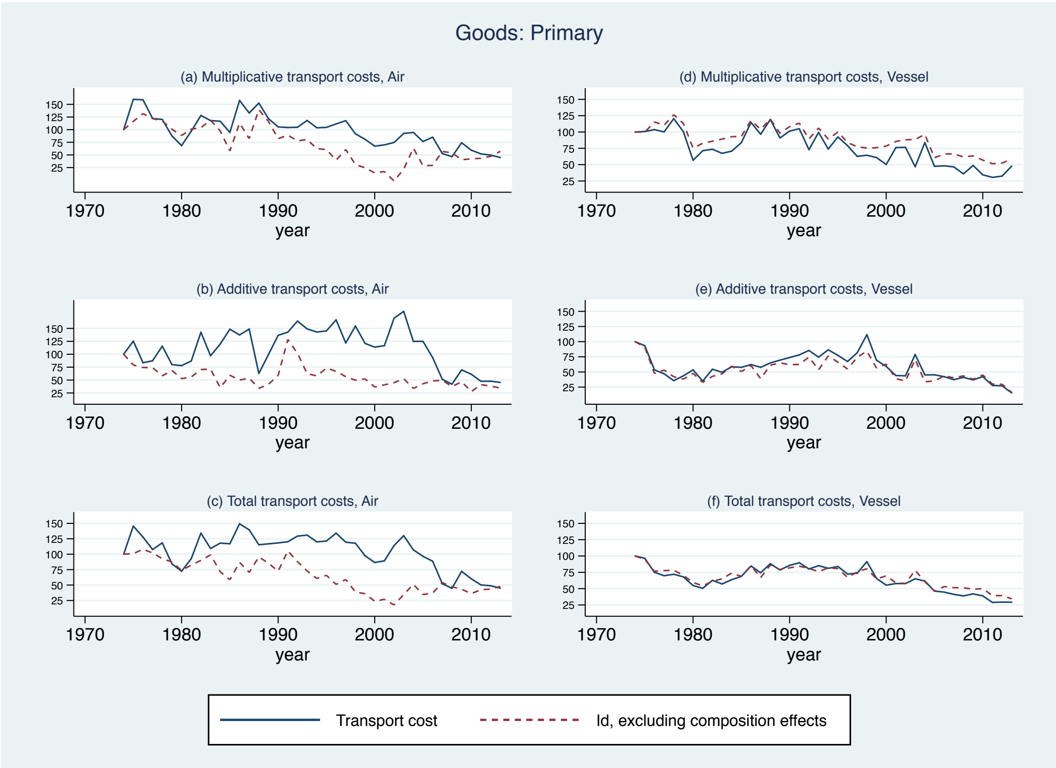


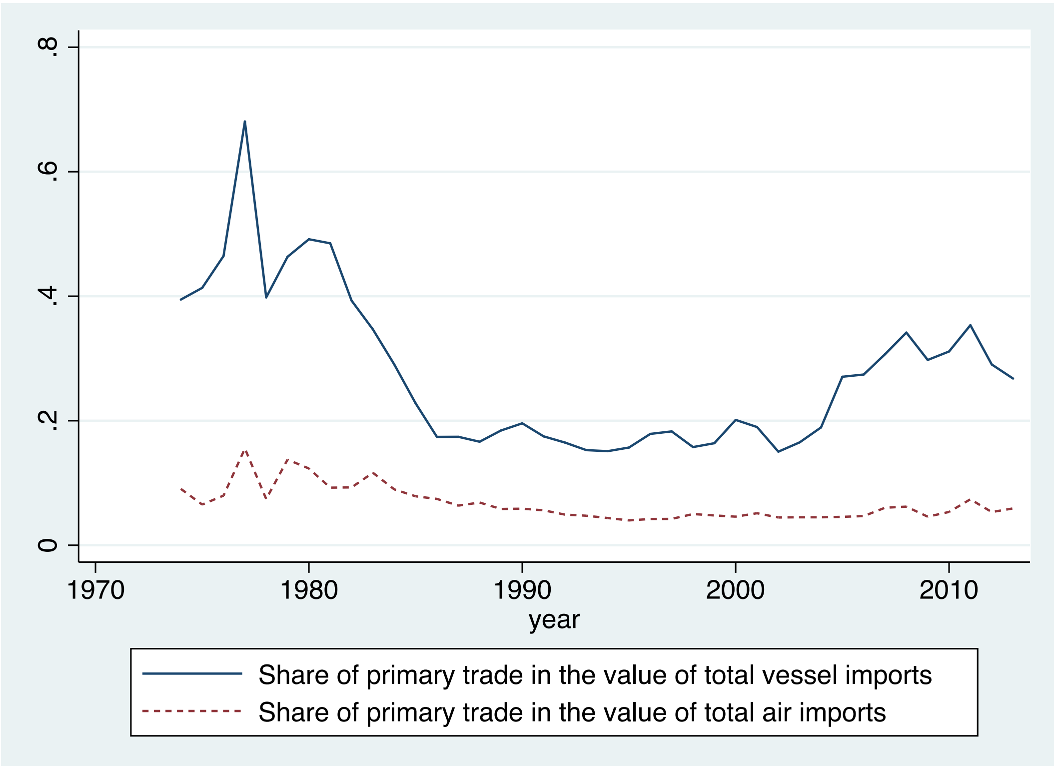
Figure 5: Transport costs (with and without composition effects), Primary goods



reduced by 50% between 1974 and 2013, and this is mainly attributable to a reduction in the "pure" transport costs. This stands in contrast with Hummels (2007), which obtained that the "pure" transport costs had decreased more (over 1973- 2004) than the unfitted ones, suggesting an important role to composition effects. As noted above, this difference of results can be explained by the difference in methodology. Whereas Hummels (2007) attributes all changes that are not in the ad-valorem component to composition effects, we show that part (and as a matter of fact, most) of these changes do come from a reduction in the "pure" transport costs, in their additive dimension.

Second, composition effects are more pronounced in ocean 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 "pure" additive costs. In line with Hummels (2007), these results confirm the important role of composition effects in maritime transport costs. The direction of the effects differs though. Whereas Hummels (2007) obtains a more pronounced reduction in the "pure" transport costs than the unfitted series, we obtain the opposite result. On top of the reduction of the "pure" transport costs, overall maritime transport costs have reduced over time because of the composition of flows, **one potential explanation being the reduction in the share of bulky goods linked to the declining share of primary goods in total trade. Aller plus loin? mettre la part du primary dans le temps? Pertinence de cette hypothese?**

Figure 6: Share of primary goods in the value of total US imports



5 Robustness checks

Robustness to the specification of the estimated equation.

Robustness to the separability assumption Ie, estimate

$$\log(\frac{p_{ik}}{\widetilde{p}_{ik}} - 1) = \log(\tau_{is} - 1 + \frac{t_{is}}{\widetilde{p}_{ik}}) + \exp(\epsilon_{ik})$$

To do on 100 products (s), 50 countries (the most important?)

what else?

6 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%. 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 also use the time dimension of our data to characterize the evolution of transport costs. After correcting for composition effects, we find that all types of transport costs have been roughly constant from 1974 to 1984 and then steadily decreased by 40% over the period 1984-2013. Yet, this steady decline hides shifts in the relative importance of additive and ad-valorem. While most of the early decline in air transport costs can be explained by the ad-valorem component, this component nearly doubled in the 2000s. Further, the inclusion of additive costs yields to the conclusion the decrease of overall trade costs are decreased in air transport and ocean shipping roughly the same path and the same magnitude of order. This last result stands in contrast with related studies (Hummels, 2007, Behar and Venables, 2011). 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 ge 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.

References

Alchian, A. A. and Allen, W. R. (1964), *University Economics*, Belmont, CA: Wadsworth Publishing Company.

Alessandria, G., Kaboski, J. and Midrigan, V. (2010), "Inventories, Lumpy Trade, and Large Devaluations", *American Economic Review*, vol. 100 n° 5: pp. 2304–39.

Anderson, J. and Van Wincoop, E. (2004), "Trade Costs", *Journal of Economic Literature*, vol. 42 n° 3: pp. 691–751.

Behar, A. and Venables, A. J. (2011), "Transport costs and International Trade", in A. de Palma, E. Q. R. V., R. Lindsey (editor), *A Handbook of Transport Economics*, Cheltenham: Edward Elgar Publishing Ltd.

Disdier, A.-C. and Head, K. (2008), "The Puzzling Persistence of the Distance Effect on Bilateral Trade", *The Review of Economics and Statistics*, vol. 90 n° 1: pp. 37–48.

Glaeser, E. L. and Kohlhase, J. E. (2004), "Cities, regions and the decline of transport costs", *Papers in Regional Science*, vol. 83: pp. 197–228.

Head, K. and Mayer, T. (2004), "The empirics of agglomeration and trade", in J.V. Henderson, J. T. (editor), *Handbook of Regional ad Urban Economics, Volume IV*, Amsterdam: North-Holland.

Hornok, C. and Koren, M. (2015a), "Administrative Barriers to Trade", *Journal of International Economics*, vol. 96 n° 1: pp. 110–122.

Hornok, C. and Koren, M. (2015b), "Per-Shipment Costs and the Lumpiness of International Trade", *Review of Economics and Statistics*, vol. 97 n° 2: pp. 525–530.

Hummels, D. (1999), "Have International Transportation Costs Declined?", Working paper, purdue university.

Hummels, D. (2007), "Transportation Costs and International Trade in the Second Era of Globalization", *Journal of Economic Perspectives*, vol. 21 n° 3: pp. 131–154.

Hummels, D. and Skiba, S. (2004), "Shipping the Good Apples Out? An Empirical Confirmation of the Alchian-Allen Conjecture", *Journal of Political Economy*, vol. 112.

Irarrazabal, A., Moxnes, A. and Opromolla, L. D. (2015), "The Tip of the Iceberg: A Quantitative Framework for Estimating Trade Costs", *The Review of Economics and Statistics*, vol. 97 n° 4: pp. 777–792.

Jacks, D. S., Meissner, C. M. and Novy, D. (2008), "Trade Costs, 1870-2000", *American Economic Review, Papers and Proceedings*, vol. 98 n° 2: pp. 529–534.

Krugman, P. (1987), "Pricing-To-Market When the Exchange Rate Changes", in Arndt, S. and Richardson, J. (editors), *Real-Financial Linkages Among Open Economies*, MIT Press, Cambridge MA, pp. 49–70.

LAFOURCADE, M. and THISSE, J.-F. (2011), "New Economic Geography: the Role of Transport Costs", in A. DE PALMA, E. Q. R. V., R. LINDSEY (editor), *A Handbook of Transport Economics*, Cheltenham: Edward Elgar Publishing Ltd.

LASHKARIPOUR, A. (2016), "Worth its Weight in Gold: Product Weight, Trade Costs, and Trade Patterns", .

LIMAO, N. and VENABLES, A. (2001), "Infrastructure, Geographical Disadvantage, Transport Costs and Trade", *World Bank Economic Review*, vol. 15 n^{o} 3: pp. 451–479.

MARTIN, J. (2012), "Markups, Quality, and Transport Costs", *European Economic Review*, vol. 56: pp. 777–791.

MELITZ, M. (2003), "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity", *Econometrica*, vol. 71 n^{o} 6: pp. 1695–1725.

NOVY, D. (2013), "Gravity Redux: Measuring International Trade Costs with Panel Data", *Economic Inquiry*, vol. 51 n^{o} 1: pp. 101–121.

SAMUELSON, P. (1954), "The Transfer Problem and Transport Costs, II: Analysis of Effects of Trade Impediments", *Economic Journal*, vol. 64: pp. 264–289.

SORENSEN, A. (2014), "Additive versus multiplicative trade costs and the gains from trade", *Canadian Journal of Economics*, vol. 47 n^{o} 3: pp. 1032–1046.

WOOLDRIDGE, J. M. (2001), *Econometric Analysis of Cross Section and Panel Data*, MIT Press Books, The MIT Press, 1 edition.

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.

Changer la facon de presenter les resultats, pour harmoniser avec la

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 $\ln(\frac{p_{ik}}{\widetilde{p}_{ik}} - 1)$

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

Year	1974	1980	1990	2000	2010	2013
With only Iceberg Trade Costs						
Mean	1.069	1.054	1.050	1.036	1.042	1.034
Median	1.054	1.038	1.044	1.025	1.034	1.029
Standard Error	0.052	0.049	0.039	0.033	0.037	0.024
With Additive & Iceberg Trade Costs						
Additive term						
Mean	0.026	0.020	0.018	0.013	0.011	0.010
Median	0.011	0.005	0.008	0.005	0.004	0.005
Standard Error	0.040	0.041	0.033	0.028	0.024	0.020
Iceberg term						
Mean	1.036	1.023	1.024	1.017	1.026	1.017
Median	1.027	1.016	1.016	1.012	1.022	1.017
Standard Error	0.032	0.025	0.021	0.016	0.023	0.012
# observations	14955	16118	24958	35027	40279	39351

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

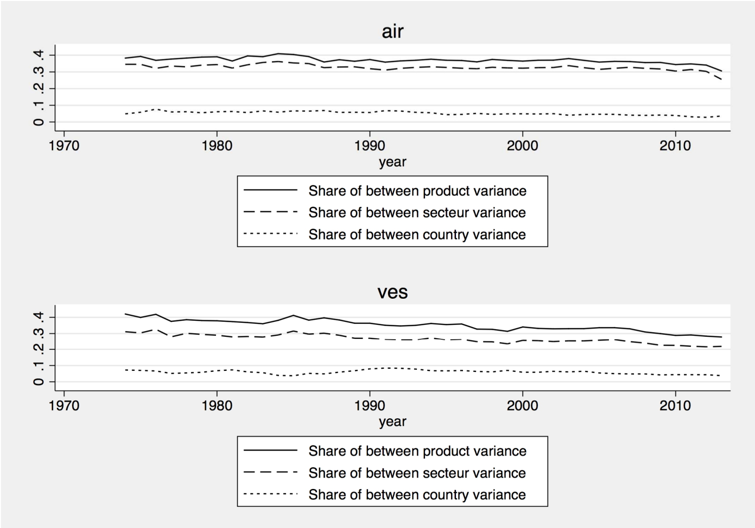
Table 5: Vessel: Transport costs estimates, 3 digit (selected years)

Year	1974	1980	1990	2000	2010	2013
With only Iceberg Trade Costs						
Mean	1.098	1.065	1.057	1.051	1.040	1.036
Median	1.096	1.055	1.046	1.049	1.036	1.033
Standard Error	0.053	0.040	0.032	0.028	0.020	0.018
With Additive & Iceberg Trade Costs						
Additive term						
Mean	0.051	0.034	0.027	0.028	0.025	0.015
Median	0.029	0.023	0.017	0.022	0.019	0.008
Standard Error	0.085	0.046	0.040	0.043	0.025	0.020
Iceberg term						
Mean	1.054	1.031	1.033	1.025	1.019	1.022
Median	1.049	1.024	1.028	1.021	1.018	1.018
Standard Error	0.041	0.023	0.022	0.021	0.018	0.018
# obs	19007	17356	28383	36090	37748	38473

Notes: 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 7.

Figure 7: Variance decomposition (observed cif-fas price gap)



Two interesting results emerge from Figure 7. 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 Ocean transport, even if the difference between the between-country 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 that 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
With only Iceberg Trade Costs						
Mean	1.066	1.058	1.052	1.033	1.037	1.032
Median	1.052	1.044	1.041	1.021	1.027	1.026
Standard Error	0.056	0.054	0.046	0.040	0.036	0.025
With Additive & Iceberg Trade Costs						
Iceberg term						
Mean	1.035	1.026	1.031	1.015	1.021	1.016
Median	1.025	1.017	1.019	1.010	1.017	1.014
Standard Error	0.036	0.028	0.030	0.021	0.024	0.015
Additive term						
Mean	0.026	0.021	0.017	0.012	0.012	0.010
Median	0.012	0.006	0.006	0.005	0.004	0.004
Standard Error	0.039	0.042	0.033	0.027	0.029	0.019
# obs	14944	16844	25307	35005	38475	39460

Notes: 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).

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 Methodolgy

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

$$\widehat{\tau}_{ikt} = \exp\left(\delta + \sum_{i \neq \text{AFG}} \alpha_i.\mathbb{1}_i + \sum_{k \neq 011} \beta_k.\mathbb{1}_k\right).\exp\left(\sum_{t \neq 1974} \gamma_t.\mathbb{1}_t\right).\exp\left(\epsilon_{ikt}\right)$$

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

Year	1974	1981	1989	2001	2009	2013
With only Iceberg Trade Costs						
Mean	1.098	1.061	1.058	1.051	1.042	1.036
Median	1.094	1.051	1.048	1.045	1.038	1.031
Standard Error	0.060	0.038	0.036	0.030	0.023	0.020
With Additive & Iceberg Trade Costs						
Iceberg term						
Mean	1.054	1.034	1.028	1.028	1.024	1.021
Median	1.049	1.030	1.024	1.025	1.026	1.018
Standard Error	0.043	0.026	0.025	0.021	0.016	0.013
Additive term						
Mean	0.046	0.026	0.031	0.024	0.021	0.015
Median	0.029	0.013	0.019	0.015	0.013	0.008
Standard Error	0.068	0.044	0.037	0.035	0.031	0.023
# obs	19196	17916	29387	36677	37643	38820

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

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

	Year					
	1974	1981	1989	2001	2009	2013
R2						
Term I only	0.48	0.49	0.50	0.50	0.45	0.35
Terms A & I	0.63	0.66	0.65	0.66	0.54	0.45
SER						
Term I only					0.88	0.93
Terms A & I					0.80	0.86
Log-likelihood						
Term I only	-17505.55	-21813.46	-30960.56	-44067.62	-49375.57	-53197.87
Terms A& I	-14895.81	-18589.91	-26553.53	-37297.93	-45747.57	-49899.14
AIC criteria						
Term I only	36243.10	44966.91	63417.12	89747.24	100317.13	107963.73
Terms A & I	31873.63	39495.82	55777.05	77439.85	94059.14	102224.28
Test LL						
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: R^2 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
R^2						
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
SER						
Term I only					0.79	0.82
Terms A & I					0.69	0.75
Log-likelihood						
Term I only	-16460.10	-16951.61	-26771.44	-39008.34	-43888.90	-47161.62
Terms A& I	-12743.65	-13546.92	-21752.77	-33280.96	-39078.86	-43399.22
AIC criteria						
Term I only	34464.19	35491.21	55272.87	79800.67	89459.80	95987.23
Terms A & I	28271.29	29877.84	46595.55	69743.91	81155.73	89692.44
Test LL						
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: R^2 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.

Based on this equation, we deduce after estimation that:

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

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

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

As such, the index of transport costs in year t (relative to the reference year 1974) Γ_{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 Γ_t^{adv} such that:

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

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:

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

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

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

Noticing 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:

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

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:

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

where $\widehat{\tau}_t^{adv}$ and $\widehat{t}_t$ have been estimated (by year) as explained in Section 2, $\widehat{\tau}_t^{adv} - 1$ measuring the ad-valorem transport cost component and $\widehat{t}_t$ 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):

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

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 $x = \{air, ocean\}$.

D.2 At the sector level

expliquer comment la repartition entre all, primary, ...