On the relative importance of iceberg and additive transport costs in international trade

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Abstract

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1 Introduction

Defined as the costs associated with the exchange of goods across national borders, trade costs remain central in international economic analysis. A major obstacle to international economic integration, trade costs have been pointed by Obstfeld and Rogoff (2000) as a major suspect for explaining the major puzzles in international macroeconomics. Historical perspective show that indeed, trade costs variations are a major determinant of the level of trade flows. Jacks *et al.* (2008) estimate that trade cost declines explain around 55 percent of the pre World War I trade boom and 33 percent 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%. 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.

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.* ~~Among them, the latter are often said to~~ have dramatically 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 costs 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 shipping, 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 value, decline in trade prices ~~are~~ much less obvious, even if the rise in containerization lowered shipping costs from 3 to 13%. Studies overviewed by Behar and Venables (2011) are consistent with those results: the fall in measured transport costs has been relatively small~~, due to the importance~~ of fuel costs and technical progress in transport, which improved speed and reliability rather than decreased costs.

~~However,~~ despite the decrease in distance-related costs[1], several papers (mostly based on empirical estimates of the gravity equation) in the last decade have shown that distance remained a major obstacle to trade (~~see~~ e.~~—~~g. Head and Mayer, 2004 and Disdier and Head, 2008). Anderson and Van Wincoop (2004) estimate that average trade costs for industrialized countries put up to 170% markups over production costs, divided into 55% distribution costs and 74% international costs ($1.7 = 1.55 \;\; 1.74 \;\; 1$). Again, the latter comprises 44% border-related trade barriers and 21% transportation costs. That means that transportation costs are higher than each component of border costs taken separately (namely, 8% for tariff and non-tariff costs, 7% for language differences, 14% for for currency differences and 9% for other costs).[2]. Therefore, the share of transport costs in the consumer price of manufactured goods remains high (Lafourcade and Thisse, 2011). Besides, Combes and Lafourcade (2005) emphasize that the figures provided by Anderson and Van Wincoop (2004) should be considered as a a downward benchmark, and could be higher in developing economies. Despite technical progress and infrastructure development, transport costs remain large and deserve attention. In that respect, Behar and Venables (2011) support that the elasticity of trade with respect to freight is around -3, ~~a figure by no means negligible~~.

Our purpose in this paper is to provide ~~renewed~~ results on the size of transportation costs over

[1] Behar and Venables (2011) suggest freight costs account for two thirds of the effect of distance, the remaining third ebmoyding more or less the effect of time

[2] $1.44 = 1.08 \;\; 1.07 \;\; 1.14 \;\; 1.09$)

time explicitly distinguishing between multiplicative and additive parts. Following Samuelson (1954), standard models of international trade have usually relied on the iceberg cost hypothesis, implicitly reducing trade costs to their transport part, and modelling the latter as an *ad valorem* tax equivalent (ie, as a constant percentage of the producer price per unit traded)~~, making~~ more expensive goods costlier to trade. However, many common empirical facts support the existence of additive costs: pricing structure in shipping, additive tariffs, distribution costs... often exhibit (at least partly) an additive structure (see Irarrazabal *et al.*, 2015). ~~Besides, the~~ additive versus iceberg trade costs is not a new debate in the international trade literature. The famous Alchian and Allen conjecture (Alchian and Allen, 1964), which 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 demand for more expensive/higher quality product goods should increase with trade cost ("shipping the good apples out"). Martin (2012) gives a strong empirical support to this conjecture: based on a very disaggregated firm-product-level database of French exporters, he finds that firms charge higher fob unit values on exports to more remote countries, whereas the iceberg hypothesis would imply the opposite. Hummels and Skiba (2004) also find some strong evidence in favor of the Alchian-Allen conjecture: the elasticity of freight rates with respect to price is estimated well below unity, in contradiction with the iceberg assumption. Also, their estimates implied that doubling freight costs increases average fob export prices by 80-141 percent, consistent with high quality goods being sold in markets with high freight costs. Conversely, Lashkaripour (2015) finds strong empirical support for the iceberg hypothesis when ~~considered products are sufficiently disaggregated.~~ Based on US imports data, he finds that a 10% increase in the price of an item increases the shipping cost by 9.5%. The additive structure of trade costs emerges only when weight is forced to be independent of price. Besides, Lashkaripour (2015) supports that higher-priced, still exported to faraway markets, varieties are heavier and involve proportionally higher shipping costs, the latter increasing the relative demand for high-markup varieties. Markups would therefore be the driving force for explaining the "shipping the good apples out" effect in the presence of *ad-valorem* trade costs.

A correct modelling of transport costs is also important for taking proper account of several key features of international trade. For example, the existence of additive costs may explain a large number of zeros in bilateral trade flows, and more generally, the granularity of trade flows. Relying on Spanish and US transaction-level trade data, Hornok and Koren (2015) find that additive trade costs ~~of~~ are associated with less frequent and larger shipments, i.e. more "lumpiness", in international trade; in other words, exporters wait to fill completely a container before sending it abroad, to decrease as much as possible the number of shipments. Besides, several recent papers show that ~~it has~~ non trivial effects when assessing the welfare effects of trade liberalization. Sorensen, 2014 extends Melitz (2003)'s seminal model of international trade by including ~~per-unit (additive)~~ trade costs, in addition to iceberg/multiplicative costs. 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 multiplicative costs. The difference arises from dissimilar adjustments at the extensive margin - fewer firms enter into the export market following a reduction in additive costs. ~~This result is empirically confirmed~~ on Norwegian firm-level data for 2004 by Irarrazabal *et al.* (2015), ~~who find~~ that an additive import tariff reduces welfare and trade by more than an identically-sized multiplicative tariff.

Our paper stands at the crossroad of these two strands of the literature, the first one dealing with the dynamics of transport, and more generally trade costs over time, the second one focusing on the measurement and nature of the latter. More precisely, we provide estimates of the relative importance of additive and multiplicative transport costs over a large time dimension - several decades. To do so, we update the detailed US customs, sector-level data from the US Imports of Merchandise used by Hummels (2007). Therefore, our period of study runs from 1974 to 2013. Closely related to this paper is the work by Irarrazabal *et al.* (2015), who develop a structural framework for inferring additive trade costs from firm-level trade data. Based on Norwegian firm-level data, their results suggest that additive costs are on average 14 percent, relatively to the median price, and that they are strongly correlated with standard proxies for trade costs (like e. g., distance). However, while our data requires that we focus only on transportation costs, our approach departs from theirs in several key aspects.

First, our theoretically agnostic approach aims at letting the data speak, and provides a fairly simple framework for assessing *both* multiplicative and additive parts of transportation costs, which may prove to represent a non-negligible advantage for calibrating related models; to our best knowledge, our paper is the first to provide such an extensive quantitative assessment of the shares of multiplicative and additive costs in total transport costs. Second, we provide, through standard measures of "goodness-of-fit", an empirical assessment of what standard international trade models lose by skipping additive transport costs. Third, the time dimension of our data allows us to characterize the evolution of transportation costs, and more precisely the dynamics of the relative share of each specific (multiplicative and additive) cost over a forty years time span; to our knowledge, no firm-level database is able to provide such a time coverage. Fourth, we are also able to discriminate our results by transport mode (air and vessel).

Finally, our analysis is also indirectly related to a large strand of the international trade literature assessing the impact of trade costs on international exchanges. Following Anderson and Van Wincoop (2003) and Anderson and Van Wincoop (2004), there has been a huge bunch of articles relying on gravity equations to infer indirectly trade costs as tariff equivalents, or losses related to various kinds of trade barriers - many of these works are surveyed in Anderson and Van Wincoop (2003); among the various subsequent works, see in particular Anderson and Yotov (2010), Novy (2013) or Chen and Novy, 2012). However, our purpose in the present paper is different. We first infer directly transport costs from price data, discriminating between multiplicative and additive parts. In a second step, following an approach similar to Behar and Venables (2011), we relate the previous measures to traditional determinants of transport costs (like e. g., distance), in order to understand how differently the latter impact the multiplicative and additive transport costs.

XXX Here a summary of our results and contribution XXX

The next section presents our general methodology and our database. Section 3 reports our baseline estimates for multiplicative and additive measures of transport costs across time, as well as a number of robustness checks. Section 4 discusses the results of estimates relating traditional determinants of transport costs to the previous measures, while Section 5 XXX has yet to be discussed!!! XXX. The last section concludes.

2 Data Sources and Empirical Methodology

2.1 A measure of transportation costs

Our strategy for representing transportation costs is relatively standard, and consists in exploiting the difference between commodity-level export and prices. We first use values, quantities and freight costs to recover free-on-board (FOB) and cost-insurance-fret (CIF) prices, by goods, origins and transportation mode. More precisely, the (unit) FOB price is computed as the total customs value divided by the shipping weight; in other words, it is the price for 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 FOB price. Strictly higher than 1, the variable provides therefore with a measure of transport costs as a proportion of the good's price.

To have the import price of the good (CIF price), next to the export price (FOB price) is highly valuable. Indeed, this allows us thus to estimate both the *levels* of the iceberg trade costs and of the additive trade costs. This differentiates us from Irarrazabal *et al.* (2015), that can only estimate the ratio of additive costs as a share of the tola price. However, note that this measure based on *freight* cost ignores another dimension of transportation 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.

2.2 Database

Even if the data of transportation costs we rely could be available at the firm-level, the use of a nonlinear estimator (see below) triggers computational limitations that do not make them a likely option. A product-level bilateral database of CIF-FOB ratios is theoretically possible, and could be built from the well-known UN's COMTRADE data. Unfortunately, Hummels and Lugovskyy (2006) show that issues inherent to the construction of data (especially the use of "mirror" flows) make this database unreliable for our purpose.

We decide therefore to use database for a single country, but with strong statistical reliability arising from a single, trustworthy customs origin. More precisely, the empirical analysis relies on yearly data from US annual Imports of Merchandise provided by the Census bureau[3], spanning from 1974 to 2013. Based on customs declarations, this dataset inventories all imports (both values and quantities) by origin to the United states at the HS 10-digit highly disaggregated level, with a concordance code to the SITC 5-digit coding system. In addition, the database reports information regarding freight expenditures and transportation mode (Ocean Vessel and Air). The first will be crucial to compute transport costs (see below), the second will alow us enlightening potential different dynamics of transport costs across transportation mode.

Due to the abovementioned computational limitations, data are reaggregated at the 3- and 4-digit level: comparing different levels of aggregation will be useful to check differences and the presence of

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

biases precisely due to aggregation. Depending on the considered year, this leaves us with around 200 (3-digits) and 600-700 (4-digits) products.

2.3 Key empirical specification

Our purpose is to provide estimates over time of the relative shares of multiplicative and additive costs among total transport costs. To do so, we start from a very simple equation, quite alike the one proposed by Hummels (2010):

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

or as a ratio

$$\frac{p}{\widetilde{p}} = \tau + \frac{t}{\widetilde{p}} \tag{2}$$

This equation relates the ratio of the consumer price (ie, cif price, denoted p) to the producer price (ie, fob price, denoted $\widetilde{p}$) to the two types of costs (multiplicative and additive). Iceberg trade costs are denoted τ (with $\tau = 1$ meaning no iceberg trade costs) while additive trade costs are labeled t (with $t = 0$ implying no additive trade costs). We estimate this equation for each year over the period 1974-2013, and for each of the two transportation modes reported (air or vessel), on a sectoral-origin country basis. Let us denote i the origin country and k, the sector. Hence, the equation to be estimated is given by:

$$\frac{p_{ik}}{\widetilde{p}_{ik}} = \tau_{ik} + \frac{t_{ik}}{\widetilde{p}_{ik}} \tag{3}$$

2.4 Estimation strategy and econometric concerns

Step 1. We transpose the approach by Irarrazabal *et al.* (2015) by considering that both multiplicative and additive costs are separable between origin country and products, in a multiplicative way for the former and an additive way for the latter. In other words, τ and t from equation 3 become:

$$\tau_{ik} = \tau_i \times \tau_k \tag{4}$$

$$t_{ik} = t_i + t_k \tag{5}$$

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

$$\frac{p_{ik}}{\widetilde{p}_{ik}} = \tau_i \times \tau_k + \frac{t_i + t_k}{\widetilde{p}_{ik}} \tag{6}$$

The ratio $\frac{p_{ik}}{\widetilde{p}_{ik}}$ has a "one-lower bond", since by construction, the *cif* price p cannot be lower than the *fob* price: $p > \widetilde{p}_{ik}$. Taking into account this constraint in the estimation requires to impose a multiplicative structure for the error term. More precisely:

$$\frac{p_{ik}}{\widetilde{p}_{ik}} - 1 = \left(\tau_i \times \tau_k + \frac{t_i + t_k}{\widetilde{p}_{ik}} - 1 \right) \times \varepsilon_{ik} \tag{7}$$

Log-linearization gets the following, tractable empirical equation:

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

where τ_i, τ_k, t_i and t_k are the parameters to be estimated, i.e., fixed effects specific to each origin country i and sector k, and $\epsilon_{ik}=ln(\varepsilon_{ik})$.

Still following Irarrazabal *et al.* (2015), we report a "synthetic estimate" of each type of transport cost, by averaging all $\widehat{\tau}_{ik}=\tau_i\times\tau_k$ and $\widehat{t}_{ik}=t_i+t_k$ using the values of each trade flow over total yearly trade as a weighting scheme. Therefore, we recover for each year and transportation mode a $\widehat{\tau}$ and $\widehat{t}$ that will be the results we will report for step 1.

Step 2. In step 2, we ask if the traditional determinants of transportation costs impact differently the multiplicative and additive costs estimated in the first step. Therefore, we consistently focus only on origin-country-specific transportation costs, taking the estimated τ_i and t_i from step 1 as dependent variables. In line with the trade literature, we proxy transport costs by (log of) distance and other proxies for trade costs (mainly, geographic and cultural factors).[4] More formally, we estimate, still on a yearly basis and for each transportation mode:

$$ln(\widehat{\tau}_i) = \beta_1\ln(\text{distance})+\Gamma_1\text{Gravity}+\mu_i \tag{9}$$

$$ln(\widehat{t}_i) = \beta_2\ln(\text{distance})+\Gamma_2\text{Gravity}+\nu_i \tag{10}$$

where the ln operator denotes that variables have been log-linearized, *distance* is the bilateral distance between US and the origin country i and *Gravity* is a vector of controls including the languages spoken in the country under different definitions, whether the country is landlocked, and their colonial links.

2.5 Econometric issues

Our primary interest in this paper relates to the importance of additive costs relatively to iceberg costs. Put 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 8 constraining t to be equal to zero, and compare the fitting properties/explanatory power of the restricted and complete models. This is done bye computing several standard diagnostic statistics: Pearson coefficient, Akaike Information Criterion, and the log-likelihood ratio.

The shape of our main equation 8 is such that estimations cannot be performed using standard linear estimators. Therefore, all estimates are performed using non linear least squares. 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 does not decrease from one iteration to the next. In our case, due to computational limitations implied by the size of our dataset, we implement 100 iterations and set the convergence criterion for successive parameter estimates and

[4] All those variables come from the well-known GeoDist database built by the CEPII: `http://www.cepii.fr/CEPII/fr/bdd_modele/presentation.asp?id=6`.

for the residual sum of squares at 0.01.

Finally, to control for the potential influence of outliers, we excluded observations in the 5 percent from the upper and lower tails of the distribution in the regression variables. These cut-offs are aimed at eliminating reporting or coding errors (XXX develop a little bit?XXX)

3 Results

3.1 General perspective

3.2 Differences across transportation modes

4 One step further into interpretation: transportation costs as an indicator of market structure.

5 Conclusion

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