Abstract

This paper shows French exporters set higher prices toward more distant countries. This empirical regularity suggests that firms set higher mark-ups and/or sell (more expensive) quality up-graded versions of their product when facing higher transportation costs. None of these two mechanisms is present in models of international trade. Even models with firm heterogeneity in terms of quality fail in explaining the firm pricing policy observed in the data. I demonstrate that, in existing models of trade, a necessary condition for firms to set higher mark-ups or to quality upgrade their product toward more distant countries is the presence of *per unit* rather than *iceberg* transport costs. This theoretical result coupled with empirical evidence on exporter pricing policy provide a strong argument in favor of per unit transport costs. This finding is quite important since the structure of transport costs impacts the microeconomic behavior of exporting firms but also the size of gains from trade and the composition of export flows.

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1 Introduction

Exporting firms set higher prices toward more distant countries. This stylized fact holds true when controlling for the wealth, the size or the level of competition of the destination country. This finding, detailed in section 2, relies on the use of firm level data describing bilateral trade of French exporters in 2003.¹

This empirical regularity suggests that firms set higher mark-ups and/or sell (more expensive) quality up-graded versions of their product when facing higher transportation costs. None of these two mechanisms is present in models of international trade. Actually, even the recent contributions by Baldwin & Harrigan (2007) and Hummels & Skiba (2004) fail in explaining this feature of the data.² The two papers propose alternative explanations to the observed positive relationship between average prices and distance. However, in both models, firms pricing policy is not affected by changes in transport costs. Actually, in the former paper, exporters set constant a mark-up over constant marginal cost and in the latter paper, firms are in perfect competition and price at their marginal cost: in both cases firms set the same free on bord (f.o.b.) price whatever the distance to the destination market.

The present paper shows, in existing models of international trade, a necessary condition for firms to increase their mark-up and/or upgrade the quality of their product is the presence of per unit transport costs rather than iceberg ones. Section 3 demonstrates how firms’ export prices vary with distance to the destination market depending on the nature of the demand and the structure of transport costs. In the entire analysis, the assumption of monopolistic competition is done. Transport costs are supposed to have a more general form than usual, with per unit and iceberg transport costs as particular cases. The pricing policy of exporting firms is examined under two alternative assumptions concerning the demand: a CES demand like in Krugman (1980) or Melitz (2003) and a quasi linear demand like in Ottaviano, Tabuchi & Thisse (2002) or Melitz & Ottaviano (2008). Under both forms of demand, it is first considered that a firm

¹In parallel works, Bastos & Silva (2008) and Manova & Zhang (2009) find similar patterns using bilateral firm level data on Portuguese and Chinese exports respectively.
sells the same quality whatever the distance to the destination market. Then this assumption is relaxed and the firm is allowed to set a different quality depending on destination market characteristics. Among these different variants, firms set higher prices toward distant countries only in a CES model, in presence of per unit transport costs. In that context, firms set higher mark-ups if quality is fixed. If not, they set higher mark-up and upgrade the quality of the products exported in distant markets.

This theoretical result coupled with the empirical evidence that firms set higher prices in remote countries provide a strong while indirect proof in favor of per unit transport costs. The use of per unit rather than iceberg costs to model the distance-related barrier to trade has important implications at the microeconomic and macroeconomic levels. First, in CES models under monopolistic competition such as Melitz (2003) or Krugman (1980), the introduction of per unit transport cost would induce variable mark-ups. Second, per unit transport costs distort the relative price of goods, and so the demand and composition of trade flows. This structure of transport costs allows a composition effect along the intensive margin in addition of the composition through selection effects of new new trade models. Last, the price distortion implied by per unit costs affects the gains from trade due to a reduction of transport costs. Irarrazabal, Moxnes & Opromolla (2009) show that welfare costs are 50% higher with per unit costs compared with iceberg ones.

In addition to the works cited above, this paper is related to different strands of the literature. The paper participates in the literature highlighting the impact of distance on trade prices. Hummels & Skiba (2004) and Baldwin & Harrigan (2007) proposes two distinct models explaining the positive impact of distance on prices. In these models average prices increase

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3This trick to get mark-up volatility in CES model has already been used to generate incomplete pass through via the presence of distribution costs which enter additively in firm costs (Corsetti & Dedola 2005, Berman, Martin & Mayer 2009).

4The Alchian Allen effect is a well known example of composition effect due to per unit transport costs. The Alchian Allen effect states that with per unit transport costs, the share of high quality goods increases with distance.


6Hummels & Skiba (2004) build a model in which, due to additive trade costs, the relative price of high quality goods decreases with the distance ensuring a higher share of high quality goods in the exports toward remote
through a composition effect. To get this composition effect, prices have to be different across firms. But, in these two models, a firm set identical f.o.b. prices in all its export markets. Complementary to the literature aforementioned, the present paper focuses on the impact of distance on firm pricing policy ie on individual prices rather than average prices.

Two concurrent works by Bastos & Silva (2008) and Manova & Zhang (2009) find that firms set higher prices in more distant markets. These two papers do not derive any theoretical mechanism explaining it.

The paper is also related to an old and rich literature studying spatial price discrimination. This literature explores the reaction of firms’ mark-ups to change in the distance of the buyer. One of the seminal contribution to this literature is Hoover (1937). The author shows that firm spatial pricing policy depends on the functional form of demand. In this literature, Greenhut, Ohta & Sailors’s (1985) paper is one of the few dealing with reverse dumping i.e. a positive relationship between prices and distance.

Some papers in the trade literature focus on dumping strategies: firms reduce their mark-up when exporting toward more distant countries to remain competitive. This pricing policy is also called freight absorption (Brander 1981, Brander & Krugman 1983, Ottaviano et al. 2002, Melitz & Ottaviano 2008). But most of the international trade literature gets rid of price discrimination to favor models’ tractability. In models à la Krugman (1980) or Melitz (2003), the combination of monopolistic competition, CES utility function and iceberg trade costs implies that firms do not price discriminate across countries.

Price changes across destinations may be the consequence of changes in marginal costs driven by quality upgrading. Three papers provide a theoretical framework to think about firms adapting product quality to the destination country: Hallak & Sivadasan (2009), Verhoogen (2008), and Antoniades (2008).

Last, this paper participates in the literature on the structure of transport costs. The two types countries. Since high quality goods are also more expensive, the average price increases with distance. Baldwin & Harrigan (2007) modify a Melitz-type model by assuming heterogeneity in terms of quality rather than in terms of productivity. In that context, only high quality firms, setting the higher prices, are able to serve remote countries. Therefore, the average price increases with distance.

\footnote{Assuming that quality production is costly.}
of trade frictions widely used in the literature are the iceberg and the per unit transport costs. In trade models, the iceberg formulation is the most commonly used since it contributes to models’ elegance. It has been popularized by Samuelson (1954). Since this work, this specification has been widely used, but not much questioned in the trade literature. Using data on transport costs, Hummels & Skiba (2004) find transport costs do not react proportionally to a change in prices which empirically rejects the iceberg hypothesis.

Contribution of this paper are threefold. First, it shows French exporters set higher prices in more distance countries. Second, it demonstrates in existing models of trade, prices increase with transport costs only in presence of per unit transport costs. This holds true when considering that price changes are driven by mark-ups or by quality. Third, by combining empirical evidence and theoretical discussion of prices and transport costs, this paper offers a important evidence in favor of per unit transport costs.

The aim of this paper is to point out the implications of the structure of transport costs on firm pricing policy. The highly stylized framework used here does not allow us to match other facts concerning export prices. However, the mechanism linking mark-ups, quality and transport costs can be embedded in standard models of international trade with or without quality differentiation.

The main drawback of the empirical analysis is to use unit values as a proxy for prices. Unit values are collected at the firm and product level (8 digit). Two goods, exported by the same firm in two different countries can be reported as identical CN8 products whereas they share slightly different characteristics. Despite of the precision of the data, it cannot be excluded that the price increase we observe is due to a composition effect occurring at the firm and product level. This possibility is discussed at the end of the paper. Interestingly, the more natural composition

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8 Answering Pigou (1952) criticism, Samuelson introduced (in a model à la Jevons-Pigou) a transport cost. Instead of modeling a transport sector, Samuelson assumes that "as only a fraction of ice exported reaches its destination", only a fraction of the exported good reaches its destination.

9 Nevertheless one can mention the words of Bottazzi & Ottaviano (1996) "we wonder whether the passive devotion to the iceberg approach is covering some of the most relevant issues that arise when trying to think realistically about the liberalization of world trade".

10 It is worth noting that it is impossible without assumptions to say whether prices are higher in more remote countries because of mark-up or quality adjustments.
effect biased toward the most expensive goods is the Alchian Allen effect which is based on the presence of per unit transport costs.

The rest of the paper is organized as follows. Section 2 describes the data and provides stylized fact on the impact of distance on firm pricing policy. Section 3 discusses the theoretical impact of distance on firm pricing policy depending on the nature of demand and the structure of transport costs. Section 4 reviews alternative explanations. Finally, Section 5 concludes.

2 Stylized fact: firms set higher prices in more distant countries

This section presents empirical evidence that French exporters set higher prices in more remote markets. First, the data are described. Then the empirical strategy is presented. Last, empirical results are presented and commented.

2.1 Data

The empirical analysis in this paper is based on French customs database[11]. The database covers bilateral shipments of firms located in France in 2003. Data are disaggregated by firm and product at the 8-digit level of the Combined Nomenclature (CN8). The raw data cover 96,467 firms and 10,050 products for a total exported value of 3.5 hundred billions euro. Since this paper deals with firm price discrimination, I only consider products sold by a firm on at least two markets. This restriction reduces the number of observations. Actually, only 46% of firms (44,822) export toward several destinations. However, these multi-destinations exporters realize more than 74% of French exports (in value). For each flow, the fob value and the shipped quantity (in kg) are reported. A flow is described by a firm number, a product number (CN8), and a destination country. unit value are computed as the ratio of value of the flow over its quantity.

Despite the quality of the data, there are some errors in declarations or in reporting. To deal with outliers, observations where unit value is 10 times larger or lower than the median unit value set by the firm on its different markets are dropped. This procedure keeps 73% of total exports remains.

Distance are from the dataset developed by Mayer & Zignago (2006). Real GDP and GDP per capita in PPP, from the IMF database, are used as control variables. I also use average imported unit values by country. These unit values are computed from BACI, the database of international trade at the product level developed by Gaulier & Zignago (2008). For each hs6 product and country, average unit value weighted by the quantities are computed. For product \( k \) in country \( j \): \( \text{UV}(kj) = \sum w_{ijk} \text{UV}_{ijk} \). Where \( \text{UV}_{ijk} \) is the unit value of the good \( k \) imported from country \( i \) to country \( j \). And \( w_{ijk} \) is the weight of good \( k \) exports from country \( i \). Then these hs6 unit values are merged with customs data. Thus for each product exported from a French firm in 2003, one gets the corresponding average unit value in each potential destination market.

2.2 Econometric strategy

First, we estimated the following equation:

\[
\log(P_{fkj}) = \alpha \log(dist_j) + FE_{fk} + \epsilon_{fkj}
\]

where \( P \) is the unit value computed at the firm and product level, \( dist \) is the distance between France and partner \( j \), \( FE_{fk} \) is a firm and product fixed effect, and \( \epsilon \) is the error term. Three different samples of countries are used to test the robustness of the results: all the countries, the OECD countries and the euro members. The OECD sample allows comparing prices toward countries with similar levels of development. Focusing on euro members is a way to get rid of

\[\text{Data are available on CEPII's website: http://www.cepii.fr/anglaisgraph/bdd/distances.htm. Note that with this variable, distance is destination country specific. For mono-plant firms, a distance specific to the firm and the destination country can be computed. However, this greatly reduces the number of observation. Since it does not affect the results, they are not reported here. I thank Fabrice Deferve and Farid Toubal who kindly provided me with the programs to compute these distances. Results are available upon request.}\]

\[\text{For a description of the database, see http://www.cepii.fr/anglaisgraph/bdd/baci.htm.}\]
the firm price discrimination due to (i) incomplete exchange rate pass-through and (ii) country specific tariffs.

The potential biases related to linear regression obviously matter in our case. Regressions of the log of prices on dummies for different intervals of distance are run to tackle this problem. With firm×product fixed effects, interval coefficients yield average prices set by each firm according to the distance interval. This method is used at lower level of disaggregation by Baldwin & Harrigan (2007) or Eaton & Kortum (2002) among others.

Part of the literature emphasizes the impact of the size and the wealth of the country on bilateral unit values. Baldwin & Harrigan (2007) use these controls and Hummels & Lugovskyy (2009) bring theoretical foundations to these explanatory variables in a generalized model of ideal variety. GDP and GDP per capita are used to control for these effects. The expected signs are the following. In large countries, competition is tougher which should reduce prices. By contrast, wealthy countries are expected to have a higher willingness to pay which should contribute to higher prices.

Models with quadratic utility functions suggest that prices depend on the average price on the market. Average unit values of imported products for the different countries are introduced in regressions to control for this.

Some models predict that the elasticity of price to distance is nil. Therefore, the significance of estimated coefficients is important. In the regressions, standard errors can be biased by the correlation within groups of observations. To limit this bias estimated standard errors are clustered in the country dimension. However this clustering procedure assumes a large number of clusters whereas in our dataset the number of clusters (number of countries) is rather small compared to the number of observations. This point was raised by Harrigan (2005) (see Wooldridge (2005) for a technical discussion). Results with clustered standard errors are in the core of the paper. In Appendix, the same regressions but using the alternative methodology than clustered

\[14\]

One can also interpret the GDP per capita coefficient with respect to transport costs. If the additive cost includes a distribution cost paid in the destination country, then the additive cost is expected to increase with the wealth of the country, because wages are higher there for instance (see Corsetti & Dedola 2005, Berman et al. 2009).
standard errors are presented\textsuperscript{15}

\section*{2.3 Results}

This section presents empirical findings concerning the relationship between prices and distance at the firm level. Results unambiguously suggest that distance has a positive impact on prices. Table II presents regressions of the logarithm of the price on the logarithm of distance. In all the regressions, the estimated elasticity of prices to distance is positive and almost always significant. In column (1), the sample contains all destination markets of French exporters. The estimated elasticity is 0.042. If the distance doubles, the average exporter increases its \textit{fob} price by 3\% \((2^{0.042} - 1)\). Focusing on the OECD sample (Column 2), one observes that the elasticity is larger than the last estimation. The estimated elasticity reaches 0.45. Column (3) focuses on the euro sample. This sample is interesting because the pricing to market in the euro area cannot be due to incomplete exchange rate pass-through, and there are no country specific tariffs for French goods. The elasticity is much lower and weakly significant but still positive (0.011).

\textsuperscript{15}The methodology consists in a two way error component model. The basic idea is to introduce both firm× product fixed effects and country random effects. Since one cannot run such regression, one first removes the firm and product means from all variables and then runs the random effects regressions on the transformed variables as indicated in Harrigan (2005).
Table 1: Price and distance, 2003

<table>
<thead>
<tr>
<th>Dependent variable:</th>
<th>Price (log)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1) (2) (3) (4) (5) (6) (7) (8) (9)</td>
</tr>
<tr>
<td>Distance (log)</td>
<td>0.042(^a) 0.045(^b) 0.011(^c) 0.050(^a) 0.051(^a) 0.019(^b) 0.050(^a) 0.051(^a) 0.019(^b)</td>
</tr>
<tr>
<td></td>
<td>(0.012) (0.017) (0.005) (0.010) (0.013) (0.007) (0.010) (0.013) (0.007)</td>
</tr>
<tr>
<td>GDP (log)</td>
<td>-0.004 0.000 0.003 -0.004 0.000 0.003</td>
</tr>
<tr>
<td></td>
<td>(0.004) (0.006) (0.002) (0.004) (0.006) (0.002)</td>
</tr>
<tr>
<td>GDP per capita (log)</td>
<td>0.020(^a) 0.047(^b) 0.014 0.018(^a) 0.046(^b) 0.014</td>
</tr>
<tr>
<td></td>
<td>(0.006) (0.020) (0.010) (0.006) (0.020) (0.010)</td>
</tr>
<tr>
<td>Mean UV (log)</td>
<td>0.018(^a) 0.010(^c) 0.003</td>
</tr>
<tr>
<td></td>
<td>(0.005) (0.005) (0.002)</td>
</tr>
</tbody>
</table>

Fixed effects

<table>
<thead>
<tr>
<th>Sample:</th>
<th>All</th>
<th>OECD</th>
<th>Eurozone</th>
<th>All</th>
<th>OECD</th>
<th>Eurozone</th>
<th>All</th>
<th>OECD</th>
<th>Eurozone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observations</td>
<td>1199711</td>
<td>910108</td>
<td>591733</td>
<td>1199711</td>
<td>910108</td>
<td>591733</td>
<td>1198282</td>
<td>909398</td>
<td>591268</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.003</td>
<td>0.004</td>
<td>0.000</td>
<td>0.004</td>
<td>0.005</td>
<td>0.000</td>
<td>0.005</td>
<td>0.005</td>
<td>0.000</td>
</tr>
<tr>
<td>rho</td>
<td>0.911</td>
<td>0.923</td>
<td>0.933</td>
<td>0.911</td>
<td>0.923</td>
<td>0.933</td>
<td>0.910</td>
<td>0.922</td>
<td>0.933</td>
</tr>
</tbody>
</table>

Standard errors are clustered by country.\(^c\) p<0.1, \(^b\) p<0.05, \(^a\) p<0.01
In columns (4-6) one controls for market characteristics by introducing the size (GDP) and the wealth (GDP per capita) of the destination country. One can see that the size of the country has no significant impact on prices whereas wealth has a positive impact. The distance coefficient remains positive, significant and even higher than without controls. This is particularly true for the Eurozone, where the distance elasticity is greater and more significant (column (3) vs column (6)). The point is that within the Eurozone, the closest countries from France are also the countries with the highest GDP per capita which as a strong positive impact on the \( fob \) price.

The average unit value takes into account the competition on the market. Columns (7) to (9) present the results once the average unit value is introduced. As expected, the mean unit value coefficient is positive (even though it is not significant for Eurozone sample regressions). However, even with this control, the distance coefficient remains positive and significant.

Table 2 presents regressions on distance intervals dummies. Since the dummies are collinear with the constant and the fixed effects, the first interval is dropped. For the reasons mentioned formerly, I add a firm and product specific fixed effect. To have enough information in each interval, regressions are run on the entire sample of countries. All the regressions suggest that prices increase with distance. The only point is that this increase is not always significant toward countries ranging between 1,500 and 3,000 kilometers. Exporting in close countries (less than 3,000 km) increases prices by 2 log points while exporting in remote countries (more than 12,000 km) increases prices by 14 log points. In the three regressions, an F-test allows me to reject the equality of distance intervals’ coefficients.

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16 Note that in the different regressions restricting the sample to euro countries, one observes that coefficients on distance are of smaller amplitude and weakly significant. Two points can explain it. First, the variance of distance between euro countries is really weak. The second point is that firms, to price discriminate, need segmented markets. Yet the European integration process and the adoption of the euro has greatly lessen the segmentation of euro markets which can contribute to explain why the coefficient is not always significant. The price discrimination of French exporters has actually decreased because of European integration as shown by Méjean & Schwellnus (2009).

17 Table C.1 in Appendix presents the results obtained when applying the two steps methodology developed by Harrigan (2005). With this methodology, estimated coefficients are still positive and significant and even of higher magnitude.

18 In Appendix, Table C.2 presents the results when introducing country random effects instead of clustering at the country level. Coefficients are still significant and increasing with the distance which comforts the previous results. Even close intervals become statistically significant.
Table 2: Price and distance intervals

<table>
<thead>
<tr>
<th>Dependent variable:</th>
<th>Price (log)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td>1500&lt; distance &lt;3000</td>
<td>0.024</td>
</tr>
<tr>
<td></td>
<td>(0.015)</td>
</tr>
<tr>
<td>3000&lt; distance &lt;6000</td>
<td>0.085*</td>
</tr>
<tr>
<td></td>
<td>(0.017)</td>
</tr>
<tr>
<td>6000&lt; distance &lt;12000</td>
<td>0.115*</td>
</tr>
<tr>
<td></td>
<td>(0.021)</td>
</tr>
<tr>
<td>12000&lt; distance</td>
<td>0.145*</td>
</tr>
<tr>
<td></td>
<td>(0.020)</td>
</tr>
<tr>
<td>GDP (log)</td>
<td>-0.006</td>
</tr>
<tr>
<td></td>
<td>(0.004)</td>
</tr>
<tr>
<td>GDP per capita (log)</td>
<td>0.022*</td>
</tr>
<tr>
<td></td>
<td>(0.007)</td>
</tr>
<tr>
<td>Mean UV (log)</td>
<td>0.018*</td>
</tr>
<tr>
<td></td>
<td>(0.005)</td>
</tr>
</tbody>
</table>

Fixed effects: Firm × Product

Sample: All OECD Eurozone

<table>
<thead>
<tr>
<th>Observations</th>
<th>1199711</th>
<th>1199711</th>
<th>1198282</th>
</tr>
</thead>
<tbody>
<tr>
<td>R²</td>
<td>0.004</td>
<td>0.005</td>
<td>0.006</td>
</tr>
<tr>
<td>rho</td>
<td>0.911</td>
<td>0.911</td>
<td>0.910</td>
</tr>
</tbody>
</table>

Standard errors are clustered by country. * p<0.1, ** p<0.05, *** p<0.01

Estimations suggest that French exporters increase set higher prices toward more distant markets. While highly surprising, this results seems quite robust. In earlier versions of this paper, I got similar results for year 2004 & 2005. Moreover, using similar data for Portugal and China, Bastos & Silva (2008) and Manova & Zhang (2009) respectively find out a positive impact of distance on prices as well.
3 Theory: Prices & Transport Costs

Firms can change their price with transport costs because of two different mechanisms: (1) firms can charge a different mark-up (2) they can offer a product with a slightly different quality (and with different marginal cost of production) depending on the distance to the destination market. This section discusses the impact of transport costs on mark-ups, quality and prices depending on the structure of transport costs, the nature of demand.

3.1 Production side

Assumptions on production are the standard of trade models. We assume market segmentation and constant marginal cost. The profit is the usual operational profit. Transport costs are a combination of iceberg and per unit transport costs. Last, we assume firms are in monopolistic competition.

This section focuses on a firm $f$ exporting to country $j$. It faces a transport cost when exporting. Here, no assumption is done concerning how transport costs are passed-on to the consumer but the structure of transport cost is imposed:

$$p_{cif}^{ij}(\tau_{ij}, T_{ij}, p_{fob}^{ij}) = \tau_{ij}p_{fob}^{ij}(\tau_{ij}, T_{ij}, w_f) + T_{ij}$$  \hspace{1cm} (2)

where $p_{fob}^{ij}$ is the $fob$ price, $p_{cif}^{ij}$ is the price faced by the consumer, $w$ is the marginal cost of production and $T$ and $\tau$ are the additive and multiplicative components of the transport cost. If $T$ is nil the transport cost has an iceberg form whereas if $\tau$ is one, it is a per unit transport cost.

Several hypothesis are done concerning firms behavior. First, it is assumed that that firm’s strategy in a given market is independent from its strategy in other markets. Thus, one focuses on firm pricing behavior in a given market. The second assumption is that in market $j$, the firm faces a mixed transport cost (see Equation 2). Last, it is assumed that the firm maximizes the

\footnote{This formulation is restrictive, but it allows us to highlight the different predictions one can get when modifying $\tau$ and $T$. It is similar to what use Hummels & Skiba (2004) but here it is assumed that both the ad-valorem and the additive parts increase with distance.}
following operational profit:

\[ \pi_{if} = \left[ p_{fj}^{fob} - w_f \right] q_{fj} = \left[ (p_{fj}^{ cif} - T_{fj}) / \tau_{fj} - w \right] q_{fj} \]  

(3)

where \( q_{fj} \) is the quantity sold on market \( j \) (that depends on the \( cif \) price) and \( w \) is firm specific but constant across markets.

### 3.2 CES demand

In Krugman (1980) or Melitz (2003) type models, firms face the following inverse demand:

\[ p_{fj}^{ cif} = k_j q_{fj}^{-1/\sigma} \lambda^{(\sigma-1)/\sigma} \]  

(4)

with \( k \) a positive parameter, exogenous for the firm, and \( \sigma \) the elasticity of substitution, greater than 1. In this type of model, \( k \) is in general a function the size of the destination country and the price index in the destination country. In the rest of the analysis, the \( j \) subscript on parameter \( k \) is dropped. \( \lambda \) is a taste/quality parameter. A high quality shifts up the demand for the variety. In a first step, \( \lambda \) is supposed to be exogenous.

**Exogenous quality.** Since \( \lambda \) is exogenous, it is dropped in this paragraph. This assumption is relaxed in the next paragraph.

Firm \( f \) maximizes its operational profit (eq. 5) on market \( j \) considering a CES demand (eq. 4). Since firms are in monopolistic competition the strategic variable is not important. The program is given by:

\[ \arg \max_{p_{ces,f}} \left[ (p_{fj}^{ cif} - T_{fj}) / \tau_{fj} - w \right] \left[ \frac{1}{k} (p_{fj}^{ cif})^{-\sigma} \right] \]

(5)

\[ ^{20} \text{Maximization with respect to prices or quantities yields the same results. It is also equivalent to maximize with respect to } cif \text{ or } fob \text{ prices.} \]
The first order condition of the maximization program yields:

\[ p_{ci} = \frac{\sigma}{\sigma - 1} T + \frac{\sigma}{\sigma - 1} \tau w \]  

(6)

Using the relationship between the \(f_{ob}\) price and the \(ci\) price one gets:

\[ p_{fob} = \frac{1}{\sigma - 1} \left( \frac{T}{\tau} \right) + \frac{\sigma}{\sigma - 1} w \]  

(7)

If the transport cost has the standard iceberg structure \((T = 0)\), the \(f_{ob}\) price is a constant mark-up over marginal costs. This is the textbook case of a large part of trade models (e.g. Krugman 1980, Melitz 2003, Baldwin & Harrigan 2007).

By contrast, if the transport cost is per unit \((\tau = 1)\), then the mark-up is increasing in transport costs. That is the first possible channel explaining why prices increase with distance.

Under monopolistic competition, in CES models, with iceberg transport costs, firms set the same mark-up whatever the distance to the destination country. With per unit transport costs, firms set higher mark-ups toward more distant countries.

Destination specific endogenous quality. It is possible that firms adjust the quality of their product depending on market characteristics. Here, the analysis focuses on the impact of transport cost on the level of quality produced by the firm. If quality is costly, then the relationship between prices and transport costs could be driven by changes in the quality of the exported product\[21\]

The inverse demand is given by equation [4]. In a first step, the optimal price is computed. The first order condition of the maximization of firm’s profit with respect to price gives the same

\[21\]Existing model where the quality is explicitly destination specific is Verhoogen (2008). The author sketch a model where demand has a logit form and there is not transport cost. Adding an iceberg one yields to the following conclusion: higher trade costs decrease the quality offered by the firm. Actually, in this model, an increase in \(\tau\) increases the relative price of the good which reduces the demand and finally the offered quality. In Hallak & Sivadasan (2009), heterogeneous firms facing a CES demand choose the same optimal quality for all markets. In appendix it is shown that modifying the model by assuming that firms maximize their profit independently on each market implies firms set lower quality toward the more remote countries when facing iceberg transport costs.
result as the exogenous quality case but the marginal cost depends on the quality level:

\[ p_{fob} = \frac{1}{\sigma - 1} \left( \frac{T}{\tau} \right) + \frac{\sigma}{\sigma - 1} w(\lambda) \]  

(8)

Here we see that the price depends on transport costs through \( \tau \) and \( T \) but it could also impact the price indirectly by affecting \( \lambda \) and so \( w(\lambda) \).

To find the optimal level of quality, the firm maximizes its profit with respect to \( \lambda \), replacing price by the expression of the first step. Firms maximize the following profit:

\[ \Pi = \frac{\sigma^{-\sigma}}{(\sigma - 1)^{1-\sigma}} \frac{k^\sigma \lambda^{\sigma-1}}{\tau} (T + \tau w(\lambda))^{1-\sigma} \]  

(9)

Assumption that \( w \) is exogenous is relaxed when considering that quality is market specific. Producing a better quality increases your demand but is costly. Thus, we consider that the marginal cost \( w(\lambda) \) is a function of quality. The following assumptions are done: \( \partial w(\lambda)/\partial \lambda > 0 \), \( \partial^2 w(\lambda)/\partial \lambda^2 > 0 \), \( w(0) > 0 \) and \( \partial ln(w(\lambda))/\partial ln(\lambda) \geq 1, \forall \lambda \geq 0 \). The marginal cost is a positive function of \( \lambda \) and it is convex in \( \lambda \). The first assumption is the basis of our reasoning.

If the marginal cost does not increase in quality then the prices increases cannot be thought as a quality upgrading phenomena. The second assumption ensures that it is sufficiently costly to produce quality to not choose an infinite quality. The third assumption is that even if the firm produces a nil quality, it faces a positive cost. Under this assumption, the elasticity of costs to quality is not a constant which is a necessary to have finite solution. Last, the elasticity is supposed to be greater than or equal to one for all positive level of quality. This last assumption is in fact a combination of assumptions on convexity of costs and non nil marginal costs. This is necessary to verify the second order condition. When firms are allowed to choose their quality, they do it in two steps. First they choose the optimal price, taking the quality as given. Then, they choose the optimal level of quality by maximizing the profit with optimal prices.

The first order condition with respect to \( \lambda \) is equivalent to:

\[ \frac{\partial \Pi}{\partial \lambda} = 0 \iff \frac{T}{\tau} + w(\lambda) - \lambda w'(\lambda) = 0 \]  

(10)
Let’s consider the function $H(\lambda, \tau, T) = T/\tau + w(\lambda) - \lambda w'(\lambda)$. The function $H$ is a decreasing function of $\lambda$ ($\partial H / \partial \lambda = -\tau \lambda w''(\lambda)$) because costs are convex in $\lambda$. $H()$ is a positive function of $T$. It is a negative function of $\tau$ if $T$ is non nil and does not depend on $\tau$ else.

$H(0, \tau, T)$ is positive, when $\lambda$ tends to infinity, the limit of $H(\lambda, \tau, T)$ is negative and $H$ is a decreasing function of $\lambda$. Therefore there exists a unique point $\lambda^*$ such that $H(\lambda^*, \tau, T) = 0$. To understand how $\lambda$ changes with per unit and iceberg transport costs we use the property that in the neighborhood of $\lambda^*$ the total derivative of $H$ with respect to $\tau$ or $T$ should be equal to zero. So:

$$\frac{\partial H(\lambda, \tau, T)}{\partial \tau} + \frac{\partial H(\lambda, \tau, T)}{\partial \lambda} \frac{\partial \lambda}{\partial \tau} = 0 \quad (11)$$

and

$$\frac{\partial H(\lambda, \tau, T)}{\partial T} + \frac{\partial H(\lambda, \tau, T)}{\partial \lambda} \frac{\partial \lambda}{\partial T} = 0 \quad (12)$$

Since $H$ is decreasing in $\lambda$ and $\tau$ and increasing in $T$, for the two identity to hold one must have: $\partial \lambda / \partial \tau < 0$ if $T$ is strictly positive, $\partial \lambda / \partial \tau < 0$ if $T$ is nil, and $\partial \lambda / \partial T > 0$.

Therefore if transport costs are pure iceberg, then the quality does not depend on it. If transport costs have a per unit structure, then quality increases in transport costs. Since prices depend positively on marginal costs, that marginal costs increase with the level of quality and the level of quality itself increases with per unit transport costs, then prices increase with per unit transport costs.

*Under CES demand, firms increase the quality exported when per unit transport costs increase. The quality does not depend on transport costs when the latter have an iceberg structure.*

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22Note that the derivative of $H$ with respect to $\tau$ is negative if the elasticity of costs to quality is equal to or greater than 1. If not, there is no solution to this equation. The first order condition cannot be verified but if $\lambda = 0$ which implies a nil demand.
3.3 Quasi linear demand

While CES models are omnipresent in international trade, some authors consider quasi linear demand (see Ottaviano et al. 2002, Melitz & Ottaviano 2008). In such model, firms face the following inverse demand function:

\[ p_{cif} = z - kq \]  \hspace{1cm} (13)

where \( z \) is a positive parameter, exogenous for the firms. It includes the price index\(^{23}\) \( k \) is a positive parameter capturing the degree of differentiation across varieties.

**Exogenous quality.** Here we assume that quality is exogenous. The program of the firm is to optimize its operational profit (eq. \( 5 \)) given the linear demand (eq. \( 13 \)). The first order condition yields:

\[ p_{cif} = \frac{1}{2}(z + T) + \frac{\tau w}{2} \]  \hspace{1cm} (14)

Using equation \( 2 \), one gets the following \( fob \) price:

\[ p_{fob} = \frac{1}{4}(z - \frac{T}{\tau}) + \frac{w}{2} \]  \hspace{1cm} (15)

The price net of transport cost negatively depends on transport costs whatever the structure. This has already been verified in the literature: Ottaviano et al. (2002) use a per unit transport cost whereas Melitz & Ottaviano (2008) use an iceberg one and in both models firms absorb part of the transport costs.

*Under quasi-linear demand, firms reduce their mark-ups to sell goods in more distant countries, whatever the structure of transport costs.*

**Destination specific endogenous quality.** This paragraph explores the link between prices and transport costs in a quasi linear demand model when firms chose the level of quality they

\(^{23}\)For expositional ease, we consider a population of size 1.
produce. Quality is introduced in this framework through an additive shifter as in Antoniades (2008):

\[ p^{ci} = z - kq + a\lambda \]  

(16)

In Antoniades paper the marginal cost does not depend on the level of quality. Instead, the fixed cost is increasing in quality. As shown in appendix this does not change the results concerning the relationship between prices and transport costs. In what follow, it is assumed the marginal costs is increasing in quality and convex. We further assume that \( w(0) > 0 \).

In the first step, the firms set the optimal prices, taken quality as given. The price is the same as without quality.

\[ p_{fob} = \frac{1}{2}(z + \frac{\lambda}{\tau} - \frac{T}{\tau}) + \frac{w(\lambda)}{2} \]  

(17)

Visual inspection shows quality impacts prices through two channels: it increases the prices through a demand effect and increases the marginal cost of production. Therefore, even if the marginal cost of production is exogenous, quality can impact the price. This is the case in Antoniades (2008) for instance. In a second step, the firm maximizes its profit with respect to quality level. Firm’s profit is:

\[ \Pi = \frac{1}{4k\tau}(z - T + \lambda - \tau w(\lambda))^2 \]  

(18)

The first order condition yields:

\[ H(\lambda, \tau, T) = 1 - \tau w'(\lambda) = 0 \]  

(19)

Function \( H \) is positive if \( \lambda = 0 \) and limit of \( H \) tends to negative infinite when \( \lambda \) tends to positive infinity. There exist a optimal point in which \( H \) is nil. At the neighborhood of this point, the derivative of \( H \) with respect to \( \tau \) has to be nil:

\[-\frac{\partial w(\lambda)}{\partial \lambda} - \frac{\partial^2 w(\lambda)}{\partial \lambda^2} \frac{\partial \lambda}{\partial \tau} = 0 \]  

(20)
Since costs are increasing in \( \lambda \) and convex, the equality holds if \( \partial \lambda/\partial \tau \) is negative. In this framework, quality decreases with the iceberg cost but does not depend on the per unit transport cost. Since mark-ups decrease with both structures of transport costs, the add of endogenous quality does not affect the result with per unit transport cost and strengthens the negative impact of transport costs in the case of iceberg transport costs.

Under quasi-linear demand, firms reduce the quality they export when iceberg transport costs increase. The level of quality is independent of per unit costs. Since under this framework firms reduce their mark-up, the overall effect of transport costs on prices is negative, whatever the structure of transport costs.

3.4 Discussion

The facts presented above are driven by a single key variable: the elasticity of demand. The introduction of a per unit cost changes the results concerning the relationship between prices and transport costs because it introduces a disconnection between the elasticity of demand to the \( cif \) price and the elasticity of demand to the \( fob \) price. Actually, assuming that the transport cost has both an additive and a multiplicative component, it is easy to show that the elasticities of demand to \( cif \) and \( fob \) prices are linked by the following equation.

\[
\epsilon_{fob} = \frac{\epsilon_{cif}}{1 + \frac{T}{\tau P_{fob}}} \tag{21}
\]

where \( \epsilon^m = \frac{\partial \log(\text{demand})}{\partial \log(p_m)} \) with \( m \in (cif, fob) \). In the case of pure iceberg transport cost, \( T \) is nil and the elasticities of demand to \( fob \) and \( cif \) prices are the same. By contrast, for a given elasticity of demand to the \( cif \) price, the elasticity of demand to \( fob \) price decreases in \( T \). All else equal, with an additive transport cost, the demand is less responsive to changes in prices. Therefore, remote firms are able to set higher \( fob \) prices, this allows them to compensate a part of the loss due to the lower demand they face because of freight costs.

The last discussion assumes that distance impacts the \( fob \) price only through \( T \). However, in a lot of models such as quasi linear demand models, the elasticity positively depends on
Consequently with additive transport costs, two opposite forces are at stake. The elasticity of demand to FOB price tends to decline due to the additive cost, but it also increases because the CIF price increases due to higher transport costs. In linear demand models, the price effect dominates, therefore the elasticity increases with transport costs and distance and prices decrease with distance.

4 Alternative explanation

The main part of the analysis, in this paper, implicitly assumes that prices increase because mark-ups and or marginal costs increase. However, the empirical evidence that prices increase toward more distant countries is based on unit values. While these unit values are computed at the firm level for broadly defined products, it is possible that they reflect average prices. The dataset allows to study the unit value of 8 digit level products exported by firm X. Imagine that firm X exports two goods belonging to the same 8 digit product classification. Therefore, the observed unit value is the average price of these two goods. The firm would set a higher unit value toward more distant countries because it sells more of the more expensive good. Therefore what is observed at the firm and product level would be a pure composition effect. In the literature, such composition effect can occur through two different mechanisms.

The first mechanism if a selection effect. This selection effect should look like the selection effect à la Baldwin & Harrigan (2007) but at a higher level of disaggregation. Namely, distance would select the more expensive goods. Such mechanism is entirely driven by extensive effect: the exit of cheap goods in more distance markets. However, to model such mechanism it is needed to assume that the firm has to pay a different fixed cost for each good, in each market. This seems to be a very strong assumption.

The second mechanism through which firm should export relatively a higher quantity of its expensive good is developed by Hummels & Skiba (2004). Their paper models the Alchian Allen effect at the product level but the model would remain valid at the firm and product level. The framework would be the following. First, firms face CES type demand. Second firms
compete in perfect competition. Third, each firm produces two qualities of a given good. With additive transport costs, the relative \( cif \) price of the high quality (more expensive) variety of the good decreases with distance. Consequently, in remote market, the firm faces a higher demand for the high quality version of its good. At the firm and product level, the share of goods of higher quality increases with distance. Thus, the average price of the good increases with the distance. Here the positive relationship between prices and distance is due to the additive transport costs which allows the relative \( cif \) price of the high quality good to decrease with distance. In this model, this is a pure demand effect.

Interestingly, this mechanism is build on the presence of per unit transport cost. This supports the main claim of this paper: to reproduce the positive impact of distance on prices set by exporting firm, the per unit transport costs seems more appropriated than the iceberg one.

5 Concluding remarks

This paper explores the impact of transport costs on firm pricing policy. The empirical part shows French exporters set higher prices toward more distance countries. This empirical regularity suggests that firms set higher mark-ups and/or sell (more expensive) quality up-graded versions of their product when facing higher transportation costs. None of these two mechanisms is present in models of international trade. Even models with firm heterogeneity in terms of quality fail in explaining the firm pricing policy observed in the data. I demonstrate that, in existing models of trade, a necessary condition for firms to set higher mark-ups or to quality upgrade their product toward more distant countries is the presence of per unit rather than iceberg transport costs.

In addition of explaining why firms set higher prices when facing higher transport costs, the per unit structure of transport costs has important consequences on trade models. First it allows firms to set variable mark-ups in intensively used CES models that used to exhibit constant mark-ups. Second, by distorting relative prices, it generates a new composition effect through the intensive margin in addition of the selection effect of new trade models. Last, this
structure modifies the nature of gains from trade compared with the iceberg structure as shown by Irarrazabal et al. (2009).
A Appendix. Data.

In the empirical part of this paper, prices are approximated by unit values. Values are declared free-on-board. Therefore, unit values are also free-on-board. The unit value set by firm $f$ for product $k$ exported toward country $j$ is: $P_{fjk} = \frac{V_{fjk}}{Q_{fjk}}$. Where $V_{fjk}$ and $Q_{fjk}$ are value and quantity of good $k$ exported by firm $f$ to country $j$. Unit values are well known to be a noisy measure of prices. The main criticism was formulated by Kravis & Lipsey (1974). The authors state that unit values do not take into account quality differences among products. The high level of disaggregation of the data and their firm dimension limits the main drawback of unit values i.e. the composition effect and more particularly the quality mixed effect. Actually with more than 10,000 products, the possibility to have goods with highly different characteristics within these unit values is limited.

B Appendix. Theory.

CES, monopolistic competition and endogenous choice of quality. Demand in country $j$ for a given variety with quality $\lambda$ is:

$$q_j = p_j^{-\sigma} \lambda^\sigma \frac{E}{P}$$

(B.1)

where $p_j$ is the cif price in the market $j$, $\sigma$ is the elasticity of substitution (greater than one), $\lambda$ is the quality offered by the firm on the market $j$, $E$ is the level of expenditure, and $P$ is a price aggregator. The cif price is linked to the fob price by the following formulation : $p_{cif} = \tau p_{fob} + T$ where $\tau$ and $T$ have the properties described previously.

The production function is similar to the one used in Section 3 but it varies with the quality. Producing a greater quality is costly because it increases the marginal cost, but also because it forces to pay a higher fixed cost. The profit of a firm serving country $j$ can be written:

---

24 For a recent criticism of unit values see Silver (2007). For a deeper discussion on the use of unit values as a proxy for prices for this database, see Méjean & Schwellnus (2009).

---
\[
\pi_j = \left( p_j^{fob}(\lambda) - c(\lambda) \right) q_j(p, \lambda) - F(\lambda)
\] (B.2)

For technical convenience, both the form of the marginal and the fixed costs are specified. Functional forms are the same as in Hallak & Sivadasan (2009). The marginal cost is given by
\[c(\lambda) = w\lambda^\beta\] where \(\beta\) lies between zero and one. The fixed cost is given by \(F(\lambda) = g\lambda^\alpha\). The maximization process occurs in two steps. First, the firm sets its optimal price, considering the quality as given. Then, substituting the optimal price in the profit function, the firm maximizes its profit with respect to the quality.

The profit derivative with respect to the \(fob\) leads to same result than above:
\[
p_{fob} = \frac{1}{\sigma - 1} \frac{T}{\tau} + \frac{\sigma}{\sigma - 1} c(\lambda)
\] (B.3)

Using expression (B.3), the first order condition with respect to \(\lambda\) leads to the following expression:
\[
H(\lambda, \tau, T) = \left( \frac{\sigma}{\sigma - 1} \right)^{-\sigma} \frac{E}{P} \tau^{-\sigma} \left[ \lambda^{\sigma - 2} \left( \frac{T}{\tau} + w\lambda^\beta \right)^{-\sigma} \left( \frac{T}{\tau} + w\lambda^\beta (1 - \beta) \right) \right] - g\alpha \lambda^{\alpha - \sigma + 1} = 0
\] (B.4)

The expression \(H(\lambda, \tau, T) = 0\) does not have close form solution except if one sets \(T = 0\). In that case, the (Hallak & Sivadasan 2009) solution for \(\lambda\) is:
\[
H(\lambda, \tau, 0) = 0
\]
\[
\Leftrightarrow \lambda = \left[ \frac{\sigma - 1}{\sigma} \frac{E}{P} \frac{(1 - \beta)}{\alpha} \frac{1}{wg} \right]^{1/\alpha'}
\] (B.5)

where \(\alpha' = \alpha - (\sigma - 1)(1 - \beta)\) and \(\alpha' > 0\). Visual inspection shows that quality decreases with the iceberg trade cost. If \(T = 0\) the price is a constant mark-up over the marginal cost. Since the marginal cost is an increasing function of \(\lambda\), then price decreases with distance since quality decreases.
Quasi linear demand, endogenous quality and fixed costs. The alternative way to consider the impact quality is to assume that quality affects only a fixed cost. As in Antoniades (2008) the firm maximizes the following profit:

$$\Pi = \frac{1}{4k\tau}(z - T + \lambda - \tau w)^2 - \lambda^2$$

(B.6)

Where $\lambda^2$ is a fixed cost, increasing in $\lambda$. The first order condition with respect to $\lambda$ yields:

$$\lambda^* = \frac{z - T - \tau}{4\tau k - 1}$$

(B.7)

The optimal level of quality is a negative function of both iceberg and per unit transport costs.

C Appendix. Empirical Results.
Table C.1: Price and distance, mixed effects, 2003

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<td>Distance (log)</td>
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<td></td>
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<td>GDP (log)</td>
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<tr>
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<td></td>
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<tr>
<td>Mean UV (log)</td>
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Fixed effects: Firm × Product
Random effects: Country

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<th>Sample:</th>
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Robust standard errors in parentheses
\(^c\) p<0.1, \(^b\) p<0.05, \(^a\) p<0.01
Table C.2: Price and distance intervals, mixed effects

| Dependent variable: | Price (log) | | | |
|---------------------|------------|-------------|-------------|
|                     | (1)        | (2)         | (3)         |
| 1500< distance <3000| 0.024      | 0.026       | 0.026       |
|                     | (0.002)    | (0.002)     | (0.002)     |
| 3000< distance <6000| 0.085      | 0.108       | 0.108       |
|                     | (0.003)    | (0.003)     | (0.003)     |
| 6000< distance <12000| 0.115      | 0.136       | 0.135       |
|                     | (0.002)    | (0.002)     | (0.002)     |
| 12000< distance    | 0.145      | 0.141       | 0.140       |
|                     | (0.006)    | (0.006)     | (0.006)     |
| GDP (log)           | -0.006     | -0.006      | -0.006      |
|                     | (0.000)    | (0.000)     | (0.000)     |
| GDP per capita (log)| 0.022      | 0.021       | 0.021       |
|                     | (0.001)    | (0.001)     | (0.001)     |
| Mean UV (log)       |            | 0.018       |              |
|                     |            | (0.001)     |              |

Fixed effects
- Firm × Product
Random effects
- Country
Sample: All OECD Eurozone
Observations 1199711 1199711 1198282
rho 0.000 0.000 0.000

Robust standard errors in parentheses
\( ^{c} p<0.1, ^{b} p<0.05, ^{a} p<0.01 \)
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