Are Iceberg Trade Costs Appropriate when Firms are Heterogeneous?  
— Very first and preliminary draft - please do not quote —

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Abstract

Iceberg trade costs have been a popular device in models of international trade since the early works of the late Paul Samuelson. Although convenient from a modelers’ perspective, the present paper shows that in settings with heterogeneous firms, iceberg specifications cause a severe distortions. When firms are heterogeneous, iceberg trade costs stack the deck in favor of higher productivity (lower cost) firms. In particular, with heterogeneous marginal costs, each firm faces individual trade costs, since it pays melting iceberg costs in terms of their own product. Accordingly, higher productivity firms are – by the iceberg specification – not only equipped with the better production technology but they also have access to a lower cost transport technology. This boost their willingness to export and exaggerates the trade share of higher productivity firms in the economy. Accordingly reallocation forces are distorted by the iceberg specification and welfare comparisons are flawed. We illustrate the various distortions in sign and magnitude by comparing the traditional iceberg cost specification in a Melitz (2003) model with a proper per-unit-iceberg cost specification, i.e. where each producer faces the same costs during transit of each shipped unit. In settings with homogeneous firms the problem does not occur.

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Key Words: iceberg trade costs, heterogeneous firms, trade-barriers, tariffs.

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1 Introduction

Are the most productive firms also better exporters? Well, an immediate implication of modelling trade costs as iceberg trade cost is exactly that more productive firms are also better exporters. According to the iceberg specification firms have advantages in exporting that exactly mirrors their advantages in production. Thinking about the importance of transportation costs and how most firms use the same firms in the shipping industry for exporting and thus face similar transportation costs the iceberg specification appear insufficient in capturing variable trade costs in heterogeneous firms trade models.

The costs of international trade are many, economic significant and of various natures (see e.g. Andersson and Wincoop (2004)). However, since Samuelson's work (1954) the so-called iceberg trade costs have been widely used within the trade literature as a cath-all formulation of variable trade costs. According to the iceberg formulation an exporter has to produce and ship $\tau > 1$ units per unit to arrive on the export market. The excess $\tau - 1 > 0$ units shipped are said to melt during transit and thus constitutes the trade costs. Hence more valuable goods are more expensive to trade internationally as the trade costs increases proportionally with the (exporter) value of the good. This proportionality may be reasonable when it comes to such trade costs as insurance, hedge of exchange rate risk, credit risk and the costs of trade finance. However, when it comes to transportation costs the proportionality property fails. Non-proportionality of transport costs is particularly obvious in the new new trade literature focusing on intra-industry trade in a setting where heterogeneous firms each produce a unique variety of a differentiated good. Firms within the narrowly defined industry differ in production efficiency and thus costs of producing their unique variety. There is no reason to expect that transportation costs of these varieties vary systematically with the value of the varieties. In fact, a unit transport cost formulation is arguably more appropriate in this setting. However, the literature on heterogeneous firms in international trade have adopted the conventional iceberg specification for variable trade costs.

This paper analyzes the importance of using the iceberg trade cost specification relative to a unit trade cost specification when firms are heterogeneous in production efficiency. We conduct the analysis within the Melitz (2003) model which has become the workhorse trade model in settings where firms in line with empirical evidence are assumed to be heterogeneous. To evaluate the importance of the trade cost specification we compare welfare levels (for various degrees of trade opennes) when variable trade costs are modelled as iceberg and unit trade costs respectively. We find that welfare is higher when variable trade costs are modelled as iceberg trade costs. This welfare difference is driven by that unit trade costs increases the relative price of the more efficient exporters and thus reduces the set of cheap variants that consumers like to substitute their consumption towards. Moreover we find that gains from further trade liberalization is larger (smaller) for the iceberg specification when the economy is relative closed (open), i.e. the excess welfare of the iceberg specification is hump shaped as a function of trade openness. Subsequently we show that the importance of
the trade cost specification increases in the degree of heterogeneity and that the specification is irrelevant when firms are homogeneous.

A closely related paper is Irarrazabal et. al. (2010) that also consider iceberg and unit trade cost within a heterogenous firm trade model. However, this paper complements their work by endogenizing the set of potential entrants by using the Melitz (2003) model whereas Irarrazabal et. al. (2010) stick to the Chaney (2008) model with an exogenous set of potential entrants. Moreover this paper measures the importance of the specification in terms of welfare based on an equal trade openness criterion that is easy to interpret and take to the data. Irarrazabel et. al (2010) has an empirical section showing the importance of unit trade costs and rejects the pure iceberg trade cost specification.

The importance of unit trade costs for relative prices is not new in trade theory. Alchian and Allen (1964) argued that per unit trade costs reduces the relative price and thus increases sales of the high quality good on the export market (“shipping the good apples out”). Hummels and Skiba (2004) found strong empirical support for the argument put forth by Alchian and Allen 40 years before.

More related literature to be added......

The rest of the paper is organized in the following way. Section 2 describes an extended Melitz (2003) model including both iceberg and unit variable export costs. Section 3 makes welfare comparisons of the two special cases of only iceberg costs and only unit costs. Finally Section 4 concludes and discuss further research.

2 The Model

We extend the symmetric $n$-country trade model with heterogeneous firms of Melitz (2003) to include both iceberg and unit trade costs on top of the fixed/sunk costs of exporting. The model is dynamic but in line with the literature we restrict attention to steady-states.

**Households**

The representative household supplies exogenously $L$ units of labor and maximizes utility $U = \left[ \int_{\omega \in \Omega} [c(\omega)]^{\frac{1}{1-\sigma}} d\omega \right]^{\frac{1-\sigma}{\sigma}}$ by choosing optimal consumption $c(\omega)$ for each variety $\omega$ of a differentiated good subject to the budget constraint $\int_{\omega \in \Omega} p(\omega) c(\omega) d\omega \leq E$, where $E$ is nominal income, $\Omega$ is the set of available varieties and $p(\omega)$ is the price of variety $\omega$. Demand reads $c(\omega) = EP^{\sigma-1} (p(\omega))^{-\sigma}$, where $P = \left[ \int_{\omega \in \Omega} [p(\omega)]^{1-\sigma} d\omega \right]^{\frac{1}{1-\sigma}}$ is the price index.

**Firms and firm behavior**

In a monopolistic industry each firm produces a single and unique variety of a differentiated product using labor as the only factor of production. The wage is set as the numeraire and the following costs are all specified in terms of labor. At entry a firm pays sunk entry costs, $f_e$, and subsequently draws a firm specific marginal productivity, $\varphi$, from a known and continuous distribution $G(\varphi)$ defined on the interval $[\varphi_0, \infty)$. To produce $q$ units a firm employs $l(\varphi) =$
units of labor, where \( f \) is fixed costs of production. In order to export a firm incurs various types of export costs. First, it has to pay fixed export cost of \( f_x \) per export market it serves. Second, it has to pay unit export costs \( t \geq 0 \) per unit exported\(^1\) and finally export is subject to iceberg trade costs in the sense that the firms has to ship \( \tau \geq 1 \) units per unit to arrive on the export market. At each point in time a firm is hit by an exogenous death shock with probability \( \delta \).

The CES preferences imply a constant elasticity of demand and thus firms set their prices as a constant mark-up on marginal costs. The optimal prices read \( p_d(\varphi) = \frac{\sigma}{\sigma-1} \frac{1}{\varphi} \) and \( p_x(\varphi) = \frac{\sigma}{\sigma-1} \left( \frac{\tau}{\varphi} + t \right) \), where \( p_d \) is the price on the domestic market and \( p_x \) is the price on the export market. The constant mark-up implies that the effects that trade costs have on relative marginal costs are transmitted directly into relative prices. Comparing the price of two exporting firms with different productivity we have that the relative price

\[
\frac{p_x(\varphi')}{p_x(\varphi''')} = \frac{\frac{\sigma}{\sigma-1} \left( \frac{\tau}{\varphi'} + t \right)}{\frac{\sigma}{\sigma-1} \left( \frac{\tau}{\varphi'''} + t \right)} = \frac{\frac{\tau}{\varphi'} + t}{\frac{\tau}{\varphi'''} + t}
\]

depends on trade costs, i.e. the trade costs introduces a wedge between relative prices and relative marginal costs of production. However, if only iceberg trade costs are present the wedge vanishes.

**Lemma 1** The presence unit trade costs drives a wedge between relative prices and relative marginal production costs among heterogeneous exporters.

Reduced form profit can be written as

\[
\pi_d(\varphi) = B(\varphi^{\sigma-1} f)
\]

\[
\pi_x(\varphi) = B \left( \frac{\tau}{\varphi} + t \right)^{1-\sigma} - f_x,
\]

where \( B \equiv EP^{\sigma-1} \left( \frac{\sigma}{\sigma-1} \right)^{-\sigma} \frac{1}{\sigma-1} \). Profits increase in productivity and only sufficiently productive firms are able to cover the fixed costs of operating in a given market. Only firms with \( \varphi > \varphi^* \) supply the domestic market and only firms with \( \varphi^* > \varphi^*_x \) supply export markets; where

\[
\pi_d(\varphi^*) = 0 \tag{1}
\]

\[
\pi_x(\varphi^*_x) = 0 \tag{2}
\]

defines the exit (\( \varphi^* \)) and export (\( \varphi^*_x \)) productivity threshold. We assume in line with empirical evidence that firms partition into exitters, pure domestic firms and exporters and thus impose parameter restrictions ensuring that \( \varphi^*_x > \varphi^* > \varphi_0 \).

\(^1\)Only on the goods actually arriving at the export destination.
There is free entry into the monopolistic industry and accordingly expected profits prior to entry is driven to zero.\(^2\) This free entry condition read
\[\sum_{t=0}^{\infty} (1 - \delta)^t \left( \int_{\varphi^*}^{\infty} \pi_d (\varphi) dG (\varphi) + n \int_{\varphi^*}^{\infty} \pi_x (\varphi) dG (\varphi) \right) = f_e\]
The free entry condition (\(\text{??}\)) jointly with the two cut-off conditions (1) and (2) jointly determines the industry structure (and the variables \(B, \varphi^*\) and \(\varphi^*_N\)).

**Aggregation**

The mass of firms \((M)\) derives from equating total expenditures \((L)\) with total sales, i.e.
\[L = \frac{M}{1 - G (\varphi^*)} \left[ \int_{\varphi^*}^{\infty} EP^{\sigma-1} (p_d (\varphi))^{1-\sigma} dG (\varphi) + n \int_{\varphi^*}^{\infty} EP^{\sigma-1} (p_x (\varphi))^{1-\sigma} dG (\varphi) \right]\]
which can be rewritten to
\[M = \frac{(\varphi^*)^{\sigma-1} (1 - G (\varphi^*))}{\sigma f \left[ \int_{\varphi^*}^{\infty} \varphi^{1-\sigma} dG (\varphi) + n \int_{\varphi^*}^{\infty} \left( \frac{\varphi}{\varphi^*} + t \right)^{1-\sigma} dG (\varphi) \right]} L\quad (3)\]
The price index can thus be computed as
\[P = \left[ \frac{M}{1 - G (\varphi^*)} \int_{\varphi^*}^{\infty} |p_d (\varphi)|^{1-\sigma} dG (\varphi) + n \frac{M}{1 - G (\varphi^*)} \int_{\varphi^*}^{\infty} |p_x (\varphi)|^{1-\sigma} dG (\varphi) \right]^{\frac{1}{\sigma}} = \frac{\sigma}{\sigma - 1} \left( \frac{L}{\sigma f} \right)^{\frac{1}{\sigma}} (\varphi^*)^{-1}\quad (4)\]
and welfare (defined by indirect utility of the representative household) in turn reads
\[W = \frac{L}{P} = L \frac{\sigma - 1}{\sigma} \left( \frac{L}{\sigma f} \right)^{\frac{1}{\sigma}} \varphi^*\quad (5)\]
Hence trade costs only affects welfare through the exit threshold. In this extended version of the Melitz (2003) model we find that trade liberalization irrespective of source increases welfare.

**Lemma 2** Trade liberalization through a reduction in either fixed trade costs, unit trade costs or iceberg trade costs increases welfare.

**Proof.** By using the two cut-off conditions we can write the free entry condition (\(\text{??}\)) as
\[\int_{\varphi^*}^{\infty} \left( \left( \frac{\varphi}{\varphi^*} \right)^{\sigma-1} - 1 \right) dG (\varphi) + n \int_{\varphi^*}^{\infty} \left( \frac{\left( \frac{\varphi}{\varphi^*} + t \right)^{1-\sigma}}{(\varphi^{1-\sigma})} - \frac{\varphi}{\varphi^*} \right) dG (\varphi) = \frac{\delta f_L}{f_L}.\]
It is easy to see that the left hand side decreases in \(\varphi^*, f_x, t\) and \(\tau\). Hence static comparative analysis implies that \(\frac{d \varphi^*}{d \tau} > 0\) for \(x = f_x, t\) and \(\tau\). From the welfare expression (5) we can see that welfare increases in \(\varphi^*\) and that trade costs only affects welfare through the exit threshold. This completes the proof.\(^2\)

\(^2\)In line with the literature we assume no objective time discounting and accordingly the nominal interest rate becomes zero in steady state, i.e. we do not have to discount future profits and interest on investments in sunk costs are zero implying jointly with the free entry condition that \(E = L\).
3 Comparing welfare under iceberg and unit trade costs

We cannot compare iceberg and unit trade costs directly in this setting with hetereogenous firms as there is no iceberg equivalent to a unit trade costs. If such equivalence existed the modelling specification of variable trade costs would be irrelevant. In order to compare trade costs of the same magnitude we follow Venables (1994) and compare the two types of trade costs for a given degree of openness.

We define openness \((O)\) by the share of imports (evaluated at market prices) in total domestic expenditures and thus have

\[
O = \frac{nM \int_{\varphi_0}^{\infty} EP^{\sigma-1} (p_x (\varphi))^{1-\sigma} dG (\varphi)}{M \int_{\varphi_0}^{\infty} EP^{\sigma-1} (p_d (\varphi))^{1-\sigma} dG (\varphi) + nM \int_{\varphi_0}^{\infty} EP^{\sigma-1} (p_x (\varphi))^{1-\sigma} dG (\varphi)}
\]

To evaluate the quantitative importance of the variable trade costs specification we have to consider a specific distribution function \(G\). In line with much of the literature on heterogeneous firms in international trade we assume that productivities are Pareto distributed, i.e. \(G (\varphi) = 1 - \left(\frac{\varphi}{\varphi_0}\right)^{-k}\) for \(\varphi \geq \varphi_0\) (see e.g. Helpman et. al. (2004), Chaney (2008) and Eaton et. al. (2008)). Due to the additive nature of the unit trade cost we cannot solve the model analytically despite applying the Pareto distribution and we have to rely on numerical solutions to the model in the following.

Figure 1 below plots welfare for various levels of trade openness in cases where variable trade costs are of the iceberg and unit types respectively.
It can be seen from Figure 1, that welfare is the same at the two extremes of prohibitive trade costs and zero variable trade costs as the nature of the trade costs obviously does not matter at these extremes. At intermediate levels of trade costs it shows that welfare is higher under the iceberg specification. The intuition behind this result is that a unit trade costs does not only drive a wedge between relative production costs and relative prices across boarders but also a wedge between relative production costs and relative prices among firms exporting to a given destination. An alternative interpretation is that the iceberg specification gives the most efficient firms a better export technology and thus lowers the price of the cheapest imported varieties. Obviously to meet the same openness target the export technology of the least efficient exporters deteriorates. The households thus face a "mean" preserving spread of consumer prices and households take take advantage of this by substituting consumption towards the the cheaper imported varieties. The iceberg formulation takes the economy closer towards an equilibrium with no trade frictions for the varieties with the largest market shares.

**Corollary 3** The iceberg specification overstates the welfare gains from trade when firms are heterogeneous.

We next consider the importance of the degree of firm heterogeneity. In Figure 2 below we consider the welfare gap for a given openness measure for various degrees of firm heterogeneity.

- insert Figure 2 here -

Figure 2 shows that the importance of the specification increases in the degree of firm heterogeneity and that it becomes irrelevant in the limit where firms are homogenous. In the case where firms are homogenous a unit trade costs of \( t = \frac{\tau}{\varphi} \) is equivalent to iceberg trade cost of \( \tau \).

Similarly we find cf. Figure 3 (below) that the closer substitutes the goods are the more important is the trade cost specification. The intuition is that benefit from substitution towards the varieties with better export technology becomes larger in this case.

- insert Figure 3 here -

### 4 Conclusion

We have emphasized that relying on a catch-all iceberg specification of variable trade costs may be inappropriate when firms are heterogeneous. In fact our analysis suggest that such a specification would overestimate the gains from trade. Vice versa wold a catch-all unit trade cost underestimate gains from trade. A more realistic and complete model will accordingly include both unit

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\(^3\)Figure 3 plots welfare under the two specifications for a given openness measure for various levels of \( \sigma \).
trade cost and iceberg trade costs to capture the realm of actual trade costs. However, there are costs in terms of tractability from including the unit trade cost as closed form solutions become impossible to obtain. The present paper shows that in balancing these pros and cons from including unit trade costs the degree of trade openness, firm heterogeneity and substitutionability among varieties are important factors.

References


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