

Transportation Costs and Adjustments to Trade

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This note discusses the interaction between transportation costs and trade shocks. The interactions in question are two-way, including how shocks affect transportation and how transportation affects the shocks or shapes their impact on national economies. Trade shocks in this context will be taken to mean any changes in the volume or composition of trade. Some of these changes will be high frequency in nature, others will reflect long run trends.

Transportation has traditionally either been ignored by international trade scholars, or treated reductively as an “iceberg cost”. More recently, researchers have begun providing richer modeling of transportation in order to better understand its interactions with trade. These effects can be grouped into three broad categories of interactions: transport as a non-iceberg cost; transport as a produced service; and “transport costs” more broadly defined to include a range of non-tariff barriers to trade. I discuss each of these in turn.

Non-iceberg costs

In the traditional “iceberg” formulation, transport is treated as an exogenous friction τ that is fixed and proportional to the value shipped, with the value-added of transportation services treated as pure waste, or “melt”. Given this treatment, transport costs shift relative prices so that the delivered price equals the origin price multiplied by the iceberg factor,

$p^* = p(1 + \tau)$, or as a ratio,

$$(1.1) \quad p^* / p = (1 + \tau).$$

Costs specified in this way simply introduce a wedge between origin and destination prices.

When combined with CES preferences, the most common formulation, they are used to explain

the distribution of purchases from domestic versus foreign sources, or the distribution across foreign sources depending on proximity.¹ In combination with scale economies in production, as in the New Geography or Home Market Effect literatures, iceberg costs create interesting feedback loops, as better (lower τ) access to foreign markets becomes a source of comparative advantage for firms. Beyond these two main effects, iceberg transportation costs do not interact in especially interesting ways with trade or trade shocks. Indeed, from a modeling perspective, the whole point of this specification is to introduce frictions in a manner exactly like ad-valorem tariffs and to proceed with the rest of the analysis unimpeded.

However, a slightly more general formulation better fits facts about the shape of transportation costs and yields a host of interesting interactions. Denote the price per kilogram of a good as p (so that $1/p = \text{weight/value}$), and the shipping charge per kg shipped as f . If the shipping charge is independent of the goods price, the ratio of destination to origin prices is $p^* = p + f / p$, or as a ratio $p^*/p = 1 + f / p$. Of course, the shipping charge f may be increasing in p because higher value goods require more careful handling and a larger insurance premium. We can then write the per kg shipping charge as $f = p^\beta X$, where X represents other costs shifters such as distance, port quality and so on. In this case we have $p^* = p + p^\beta X$, or in ratios

$$(1.2) \quad p^*/p = 1 + \left(\frac{\text{weight}}{\text{value}}\right)^{1-\beta} X$$

¹ Simple extensions allow the constant of proportionality to covary with simple geographical determinants such as distance between markets i and j , e.g. $\tau_{ij} = \alpha \left(\text{DIST}_{ij} \right)^\delta$.

Unless $\beta = 1$, the weight/value ratio of a product will be an important determinant of the transportation expenses incurred when trading that product. Hummels and Skiba (2004b) estimate that a 10 percent increase in product weight/value leads to a 4-6 percent increase in shipping costs measured ad-valorem, i.e. relative to the value of the good shipped.

Consider four implications for trade and trade shocks. One, compared to expression (1.1), transportation is no longer an exogenous constant, but instead depends on the composition of what is shipped. For some goods like scrap metal, the price per kg is low (weight/value is high), and the ratio p^*/p is high. That is, shipping charges drive a large wedge between the prices at the origin and destination. For computer microchips, p is very high (weight/value is very low), the ratio p^*/p is close to 1, and shipping charges drive only a small wedge between prices at the origin and destination.

Two, product weight/value, which varies widely across goods, explains far more variation in ad-valorem transportation costs than other observables including: the distance goods are shipped, the technology with which they are shipped, the quality of port infrastructure, or the intensity of competition between carriers on a trade route. Differences across countries in the product composition (weight/value ratio) of their trade largely explain why developing countries pay nearly twice as much as developed countries for transporting goods internationally.²

Three, because consumers are sensitive to delivered prices, non-iceberg costs change relative demands for products. In particular, the existence of per unit transport charges raise

² Hummels, Lugovskyy, Skiba 2009.

the relative demand for high quality goods. This is known as the Alchian-Allen effect and can be simply illustrated. Suppose I have two bottles of wine, high and low quality, with factory gate prices of \$20 and \$10. The relative price of the high quality bottle at the factory gate is 2/1. When we include international shipping at \$5 a bottle, the relative delivered price falls to 5/3, that is, the price premium for the better bottle of wine falls from 100% to 66%. Raising international shipping costs to \$10 a bottle, pushes the relative price at the point of delivery down to 3/2, or a premium of 50%. This effect significantly alters the pattern of international trade. Even within narrowly defined product categories, exporters shift the mix of goods sold toward higher price varieties when selling to destinations for which transport costs are high. The strength of this effect is greater the larger is X in equation (1.2). It is stronger for more distant markets, for countries with poor transport infrastructure, and in periods of high oil prices.³

Four, suppose the price of the same good changes over time, due perhaps to quality upgrading or the general equilibrium effects of trade liberalization on production costs. Holding shipping charges per unit, f , fixed, product price increases lower the ad-valorem cost imposed by transportation while product price decreases raise the ad-valorem cost of transport. The same is true of high frequency movements in product prices. In essence, the non-iceberg nature of transport costs act as a kind of shock absorber, dampening the transmission of product price shocks to delivered prices.

³ Hummels and Skiba 2004b

Transport as a Produced Service

I turn next to discussing the transportation charge, f , not as a trade friction but rather as the price of a produced service, with a somewhat narrow focus on the interactions between the production of transport services and trade. I examine input costs, economies and diseconomies of scale, and liberalization of cargo services.

Shocks to the global demand for and supply of oil affect the price of transportation fuels which are an important component of costs. The effect on transport has been especially pronounced in the last two decades with oil prices falling throughout much of the 1990s and then rising sharply since 2002. Data from the Air Transport Association show that airline operating costs have risen 89 percent since 2000 and much of that increase can be ascribed to fuel cost increases (between 2002Q1 and 2008Q1 jet fuel rose from 9.9% to 29.4% of airline operating expenses.) A simple back of the envelope calculation using the ATA data suggests that doubling fuel prices leads to a nearly 50 percent increase in aviation costs.

Fuel price shocks also change relative prices of internationally transported goods. Recalling the Alchian-Allen effect above, fuel prices enter the X term in equation (1.2), which means that rising fuel prices shift demands toward high value goods. In addition, different transportation modes use fuel with different intensity (in order: planes, trucks, trains, boats), which means that rising fuel prices shift demands toward goods using fuel efficient modes. As an example, time sensitive products can be sourced locally and shipped via trucks or sourced

globally and shipped via airplane in roughly the same time frame.⁴ However, the fuel intensity of the plane is as many times greater than the truck, and so its use will be much more sensitive to rising fuel prices.⁵

An important way that trade shocks interact with transport costs is through economies or diseconomies of scale. In periods of rapidly rising demand, shipping capacity becomes scarce, ports become congested, and spot shipping prices rise quickly. The reverse is true in periods of rapidly falling demand. As an example, data from Containerisation International show that the cost of shipping a standard container from East Asia to the US fell 33% from the height of the US business cycle in 1999-2000 to the low point of the US recession in 2001-2. Similarly, large bilateral trade imbalances cause ships to run fully loaded in one direction but at a fraction of capacity on the return voyage. This differential is congestion priced and leads to large differences in rates on the same trade route, depending on the direction of the flow. This effect has been especially pronounced for the US, whose bilateral imbalances with Asia are large. Since 2000, the cost of shipping containers eastbound from Asia to the US has been consistently 2-3 times higher than the cost of shipping containers westbound on the same route.

Over longer periods however, rising demand for shipping may actually lower shipping prices, especially in smaller countries with initially low trade volumes. This suggests an important secondary benefit to tariff liberalization – tariff reductions that boost trade volumes

⁴ See Evans and Harrigan, 2005, Harrigan and Venables, 2006, and Hummels and Schaur 2009b for a discussion of timeliness in trade and the substitution possibilities available to firms interested in timely delivery.

⁵ See Hummels 2009 for a calculation of fuel use intensities for different transport modes described in tonnes-km carried. Shifting from trucks to planes raises the fuel use per tonnes-km by a factor of 10-20, while shifting from local to global sources could raise the km shipped enormously.

may spur ancillary reductions in shipping costs. To explain, the capacity of a modern ocean-going liner vessel is large relative to the quantities shipped by smaller exporting nations. As a consequence, vessels may stop in a dozen ports and in different countries to reach capacity. As trade quantities increase, it is possible to more effectively realize gains from several sources.

First, a densely traded route allows for effective use of hub and spoke shipping economies – small container vessels move quantities into a hub where containers are aggregated into much larger and faster containerships for longer hauls. Second, the frequency of port calls rises, which is highly beneficial for time sensitive products⁶. Third, larger trade volumes allow for the introduction of specialized vessels (reefers, ro-ros) that are adapted to specific cargos, and larger ships that enjoy substantial cost savings relative to older smaller models still in use. Fourth, larger trade volumes induce investment in port infrastructure, and better port infrastructure is highly correlated with lower shipping costs⁷. Fifth, rising trade volumes promote entry into shipping markets and pro-competitive effects on shipping markups can substantially lower costs.

On this last point, Hummels, Lugovskyy, and Skiba (2009) systematically examine the effect of market power in shipping. They report that in 2006 one in six importer-exporter pairs was served by a single liner service, and over half were served by three or fewer. In general, large countries with higher trade volumes enjoy a greater number of shipping firms competing for their trade. To explain these facts, Hummels et al (2009) model the shipping industry as a Cournot oligopoly and determine optimal shipping markups as a function of the number of carriers and the elasticity of transportation demand faced by carriers. A key insight of the

⁶Hummels, Skiba 2004.

⁷ Limao and Venables (2001), Clark et al (2004), Fink et al (2002), and Haveman et al 2008

model is that transportation is not consumed directly; instead carriers face transportation demand derived indirectly from import demand. This implies that the impact of an increased shipping markup on the demand for transportation depends on the share of transportation costs in the delivered price of the good, and elasticity of import demand. The first effect is closely related to the wine bottle example above. For expensive goods, the marginal cost of shipping represents a smaller fraction of the delivered product price, which enables cargo carriers to charge larger markups without a large demand response.

The second effect relates to the responsiveness of trade volumes to increased prices. Suppose we have two goods for which shipping prices including markups will yield an equal 5% increase in the delivered price of the good. The first good is a differentiated product with an import demand elasticity equal to 1.1. Here, a markup that yields a 5% increase in delivered price reduces traded quantities, and therefore demand for transportation services, by only 5.5%. The second good is a highly substitutable commodity and faces an import demand elasticity of 10. Here, the markup raises prices by 5% but lowers quantities traded and demand for transportation services by 50%! In the latter case the identical markup reduces import (and therefore transportation) demand to a much greater degree, limiting the carrier's optimal markup.

The implication is that the market power of shipping firms is extremely high when they are moving goods with inelastic import demand, and when marginal costs of shipping comprise a small fraction of the overall delivered price. In these cases, it is easy to generate examples where optimal markups could be an order of magnitude higher than the marginal cost of

shipping. However, entry by rival liner companies can very quickly erode this pricing power. This suggests an especially important role for government policy in promoting competition in the transportation industries. Not only is transport an input into merchandise trade, but trade in transportation services itself could yield substantial gains for the countries involved.

Such policy might take two forms. The first is regulating monopoly in an industry that may be ripe for collusive behavior. As an example, the European Union Competitiveness Council recently concluded that cartelization in maritime shipping had led to a less competitive shipping market and higher shipping prices. The Council repealed a long standing block exemption to its competition laws that had allowed carriers serving the EU to collude in setting prices and market shares.

The second is simply allowing entry into national markets by international firms. Transportation services world-wide are tightly regulated, both in terms of which firms can enter and the service quality / safety they must provide. Recent efforts to liberalize air cargo services via “Open Skies Agreements” that allow open competition to foreign carriers have yielded substantial reductions in air freight rates.⁸ However, there is scope for significant further liberalization, primarily because there is no internationally integrated market for land-transport services. Roughly one-quarter of international trade occurs between countries sharing a land border and these flows are dominated by rail and truck services that are generally national, or at best regional, in scope. And when ocean or air carriers are employed to leap oceans or long distances, the door-to-door transport chain involves land-based modes at both ends and these costs likely represent the majority of the total transport bill. Efforts to integrate these markets

⁸ Micco and Serebrisky 2006

have been halting at best, even in cases where liberalization has already been agreed to (c.f. the North American trucking industry).

“Transportation Costs” Broadly Defined

Many scholars use the phrase “transportation costs” more broadly than I have discussed here, including in the phrase any non-tariff cost of trade. For example, information about foreign markets is almost certainly an important cost of trade, especially trade in complex and differentiated goods. Similarly, marketing and distribution costs, and product adaptation to local tastes and regulatory requirements are important costs that segment markets for all but the simplest of commodities. Space constraints preclude a systematic treatment of this broader meaning, but even focusing narrowly on transportation itself there are aspects of transport services that are qualitatively richer than simple expenditures on freight.

One important example is timeliness. A standard contract for shipping services specifies from where and to where cargos will be transported as well as a delivery schedule. More rapid transport can be purchased at a premium – priority handling in ports, faster ships or more direct routing, or upgrading to the use of air cargo. With speed comes flexibility as well – the ability to reach foreign markets in a day means that purchasing decisions can be put off until after uncertainty is resolved. This allows firms to adjust to shocks in real time.

How quantitatively important is speed and flexibility? World-wide, air cargo has grown 8.3 percent per year since 1975, much faster than trade as a whole.⁹ More directly, Hummels and Schaur (2009b) combine data on the premium paid for air shipment along with the greater transit time needed for ocean shipment estimate the implicit value that firms attach to timeliness. They find that firms are willing to pay just under 1 percent of the value of the good for each day saved in transit.

But what exactly is driving the rapid growth in air cargo? A few factors closely related to the changing nature of trade and trade shocks seem especially relevant. These are: a fall in the weight of trade, rising incomes, vertical specialization/fragmentation, testing new markets, and trade between geographically remote locations.

Above I discussed how high value goods enjoy a lower ad-valorem transport costs. The same logic can be employed to show that the premium charged for air shipping a good is decreasing in the price of the good. This means that a compositional shift in trade toward high value manufactures makes air transport feasible for a larger set of goods.

Rising incomes world-wide affect demand for air transport in three ways. One, high income households buy higher quality goods which have higher prices and therefore a lower ad-valorem transportation cost. Two, as consumers grow richer, so does their willingness to pay for precise product characteristics. That in turn puts pressure on manufactures to produce to those specifications, and be rapidly adaptable to changing tastes. Three, as evidenced by the

⁹ Hummels 2007.

success of online retailers like Amazon, delivery speed is itself an important characteristic of product quality, and will be in greater demand as income grows.

Much of recent trade growth has occurred through the fragmentation of international production processes, also known as vertical specialization.¹⁰ Multi-stage production may be especially sensitive to lags and variability in timely delivery, and both are reduced by using airplanes. Of course, airplanes move people in addition to cargo. Multinational firms with foreign production plants rely heavily on the ability to fly executive and engineers for consultations with their foreign counterparts.¹¹

Airplanes are especially useful for firms who are expanding trade by selling new goods for the first time. Consider a stylized description of export expansion. Firms begin producing for the local market, slowly expand sales within their own country, and some fraction of firms gradually expand sales abroad. When serving new markets, firms face uncertainty about demand, quantities sold are likely to be very low initially, and most trading relationships fail in a few years. All of these characteristics, initially small quantities of uncertain demand in distant markets, are precisely the characteristics that make air shipping particularly attractive.¹²

Conclusion

There is a central idea that runs through all the preceding analysis. Transportation costs are not an exogenous friction or drag on trade. Rather, they are endogenous to how

¹⁰ Hummels, Ishii, and Yi (2001).

¹¹ Cristea (2009) and Poole (2009) provide evidence showing a linkage between business travel and the ability to export.

¹² Aizenman (2003) and Hummels and Schaur (2009) examine the use of airplanes in hedging demand volatility. Evans and Harrigan (2005) and Harrigan and Venables (2006) discuss the importance of demand volatility in determining comparative advantage and industrial agglomerations.

production is organized and what is traded. Changes in product composition and product prices alter the ad-valorem impact of transport. Changes in trade volumes and trade policies affect the organization of transportation as a produced service. And changes in the organization of production alter the qualitative characteristics of transportation services demanded.

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