Transport costs and International Trade*

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1. Introduction

International trade has grown substantially faster than world income through most of the post war period,[1] and at the same time the share of manufacturing in world trade has increased substantially (WTO, 2007). Globalisation has transformed many economies, and some authors have heralded the age of 'Flat Earth' (Friedman 2005). Yet international economic interactions remain small relative to interactions that take place within national borders. Trade is choked-off by distance, by borders and by a variety of political and cultural obstacles. Integration into the world economy is widely viewed as one of the key factors underlying the success of the fastest growing economies (Growth Commission, 2008) yet many countries remain isolated and have failed to achieve this integration. Transport costs are one, amongst many, of the factors that shapes these trade patterns. This paper investigates the impact of transport costs on international trade, looking both at the influence of transport costs on trade and at the determinants of international transport costs.

The first issue we study is the impact of transport costs on the volume and nature of international trade. To what extent has the rise in international trade been driven by changes in transport costs? Why is cross-country and cross-regional experience so different? Transport costs also influence modal choice, the commodity composition of trade and the organisation of production, particularly as 'just-in-time' methods get extended to the global level. In turn, these new production methods are placing increasing demands on the transport system.

The second issue is the determinants of international transport costs. There is enormous cross-country variation in transport costs and in trade costs more generally. To what extent are these determined by geography, or by infrastructure investments or institutional barriers? Through time, the evidence is that transport costs have not fallen as much as many people might expect. We explore this paradox.

We take as organising structure the following relationship, which embeds both our questions.

$$\textit{Trade} = \mathrm{F}\{\textit{income, policy, cultural affinity, transport costs} = \mathrm{f}(\textit{distance, geography, infrastructure, trade facilitation, technology, fuel costs})\} \tag{1}$$

[1] Between 1950 and 2007 international trade grew at 6% per annum while GDP grew by 3.8%.

The relationship can be thought of as applying to any particular bilateral trade flow between a source country and a destination country and is written to reflect the different channels through which variables affect trade. Trade flows depend on characteristics of the source and destination countries, such as their economic size as reflected in income. It also depends on 'between country' characteristics such as their policy towards each other and their cultural affinity. The characteristics we are primarily interested in are transport costs which manifest themselves as freight charges and non-pecuniary costs like speed and reliability. Transport costs shape trade, and are in turn determined by underlying variables such as distance and other features of geography, infrastructure quality, trade facilitation measures, fuel costs and transport technology.

The variables in equation (1) are not exhaustive, but are indicative of the relationships that have been studied. The most frequently studied empirical part of the relationship is the gravity model of trade, which can be thought of as a reduced form that focuses on how underlying aspects of income, geography and other variables shape trade but without specifying the precise channel. For example, distance is thought to impede trade by increasing freight costs and increasing the length of transit, but may also operate through other channels such as the costs of gathering information on market opportunities. A brief review of this approach is the subject of the next section of the paper.

Section 3 of the paper turns to the effects of transport costs on trade. It reviews the evidence of cross-country variation in transport costs and uses alternative sources of data to study the influence of freight rates on trade volumes. We also consider different modes of transport in the context of the trade-off between time-in-transit delays and freight charges.

We then move on (section 4) to review literature on the determinants of transport costs. We organise this in two sections, looking first at cross-country variation, and then at the evolution of freight rates through time. This section of the paper in particular draws heavily on the work of David Hummels and his recent survey (Hummels, 2007). It also explains how transport developments enabled new forms of international organisation of production to develop and discusses the implications of such developments.

In section 5 we discuss some technical issues involved in establishing findings in this area, particularly the estimation of gravity models. The final section draws on our findings to discuss some of the broader implications. Are the trade-related benefits worth the costs of improving transport? Do lower trade costs raise incomes?

2. Gravity: the reduced form

One of the most robust – and extensively studied – relationships in economics is the gravity model of international trade. It can be thought of as a reduced form of equation (1), in which the researcher is interested in how the underlying variables influence trade flows, but does not specify the mechanisms through which effects occur. A typical empirical gravity specification would take the form

$$\begin{aligned} \text{trade}_{ij} = \beta_1 GDP_i + \beta_2 GDP_j + \tau_1 Distance_{ij} + \tau_2 Landlocked_i + \\ + \tau_3 Infrastructure_i + \tau_4 Trade\ facilitation_i + u_{ij}, \end{aligned} \qquad (2)$$

where trade is measured as exports from country i to country j . The equation is typically estimated in log linear form,[2] such that τ_1 can be interpreted as the elasticity of trade with respect to distance. Distance is a bilateral variable but most other variables – for example the landlocked dummy, measures of infrastructure quality or trade facilitation – are country-specific.[3] Many empirical studies refer to the rigorous theoretical economic foundations underpinning gravity,[4] but often ignore the potential implications for the estimation of coefficients and their interpretation; we touch on some of these issues in section 5.

Numerous gravity studies are surveyed in Anderson & van Wincoop (2004) and the main findings are as follows. Income (GDP) of both countries enters with coefficients close to unity. The bilateral distance[5] between two countries is highly significant, and typically enters with a coefficient of $\tau_1 = -0.9$ (see Disdier & Head 2008 for a meta study of values of this coefficient). A puzzle that has attracted attention is that the absolute value of the distance coefficient appears to have increased through time. Disdier & Head (2008) find that studies on data prior to 1960 produce an average estimate of around –0.75 while using data for later periods changes the mean estimated value to –0.9. Consistent with this, Brun, Carrere, Guilaumont & de Melo (2005) estimate positive coefficients for the interaction between distance and time. Of course, these findings do not mean that long distance trade

[2] For an example of a non-linear specification, see Coe & Hoffmaister (1999).
[3] Our illustrative specification emphasises the country-specific features of the exporter, but could easily include importer-specific features as well.
[4] For example, see Anderson (1979) and Bergstrand (1985).
[5] The distance measure is the great circle distance, which is the shortest distance between any two points on the earth's surface measured along the surface of the earth. The two points are usually the capital or largest commercial cities of each country, although sometimes weighted measures based on multiple cities may be used.

has declined, but simply that short distance trade has increased more than long distance. Carrere & Schiff (2004) show that the distance of the average trade flow declined steadily over the period 1962-2000. We discuss possible reasons for the continued importance of distance when we look at the determinants of transport costs in section 4.

GDP and distance typically account for 70% of the cross-country variation in trade, but other variables are also significant. Other geographical characteristics include having a common border (neighbours trade more) and country area (large countries trade less); islands trade more, but landlocked countries trade less. Limao & Venables (2001) calculate that landlocked countries trade about 60% less than their coastal counterparts with otherwise similar characteristics and Clarke, Dollar & Micco (2004) report a difference of approximately one third. Irwin & Tervio (2002) find that geographic characteristics explain about 30 to 40% of the variance of the log of the bilateral trade share of GDP.

Man-made characteristics also matter. An improvement in exporter's infrastructure from the 75th percentile to the median raises trade volumes by 28% and, f or landlocked countries, the infrastructure of transit countries also matters (Limao & Venables, 2001). Nordas & Piermartini (2004) include separate infrastructure measures – rail, roads, telecommunications, ports and airports – and find that all measures are important but that ports have the biggest impact on trade.

In addition to physical infrastructure, trade facilitation is important. Wilson, Mann & Otsuki (2005) evaluate four measures of trade facilitation: port facilities, customs handling, the regulatory environment and the availability of service sector infrastructure. Improvements in all four measures would have material impacts on both exports and imports. Behar (2009) negatively associates export volumes with export documentation, which suggests red tape can affect trade. The World Bank *Logistics Performance Index*[6] captures infrastructural and institutional contributors to transport costs and Behar, Manners & Nelson (2009) find that a one standard deviation improvement in logistics (which, for example, would put Rwanda on a par with Nigeria) would raise exports by about 46% for an average-size developing country.

[6] The Logistics Performance Index is a new dataset produced by the World Bank. It is constructed using principal component analysis based on six measures, namely (i) the efficiency of the clearance process by customs and other border agencies, (ii) transport and information technology infrastructure, (iii) local logistics industry competence, (iv) the ease and affordability of international shipments, (v) the facility to track and trace shipments and (vi) the timeliness with which shipments reach their destination. It therefore captures a broad spectrum of factors which influence transport costs.

While the gravity model is the reduced form relationship between trade, income, and geography, the task in this paper is to identify the role of transport costs in this relationship. How do transport costs affect trade, and what determines transport costs?

3. Transport costs and trade

The next step is to identify the effect of the transport cost channel in the determination of trade flows. This involves obtaining data on transport costs and investigating a form of relationship (1) which uses this information while excluding other variables that are expected to affect trade volumes only via their effect on transport costs. Rewriting equation (1) as

$$\textit{Trade} = \mathrm{F}(\textit{income, policy, cultural affinity, transport costs}), \tag{3}$$

we are interested in the strength of the last argument in the function. This section starts by reviewing the transport cost data that is available and proceeds to discuss the relationship between various transport costs measures and trade, looking across countries and over time. Different modes of transport offer different quality of service – in particular with respect to speed and reliability – in return for different freight charges, and we examine this trade-off.

3.1 Measuring transport costs.

There is wide dispersion of transport costs across countries. Table 1 gives the regional averages of the costs for shipping a standard container, where the average is taken of the cost of importing and exporting a container. It shows that clearing goods is twice as expensive in sub-Saharan Africa as in East Asia and the Pacific. Particular country examples make the point more vividly; average freight costs for a 20 foot container are about $450 in Singapore and Malaysia yet more than $5500 in Chad and the Central African Republic. Table 1 also presents transport costs in terms of the time it takes to comply with all the procedures necessary to comply with import/export regulations, inland transportation and handling but excludes port-to-port shipping. OECD countries can clear goods quickly (but not necessarily cheaply). Within the regional averages there is wide dispersion of country performance. Singapore takes an average of 3 days to clear imports; Brazil takes 12 days while neighbouring Venezuela takes 49. Chad takes 100 and Iraq takes 101. Including shipping, transporting goods from Europe to Asia takes about five weeks (Hummels, 2007).

Table 1: average costs and handling time for a 20 foot container

Region	Cost (dollars)	Time (days)
East Asia & Pacific	931	23.7
Eastern Europe & Central Asia	1678	27.6
Latin America & Caribbean	1362	19.75
Middle East & North Africa	1128	24.2
OECD	1118	10.75
South Asia	1437	32.3
Sub-Saharan Africa	2154	36.5

Table 1: Source: *Doing Business website; 2009 data* (Average calculated using data for imports and exports).

Data in Table 1 are provided by the World Bank, which uses the methodology in Djankov, Freund & Pham (2006).[7] It covers about 180 countries, is based on surveys of freight forwarders in each country, and the data are updated annually. The data for the cost of importing and exporting a standardised container of goods includes fees associated with completing the procedures to export or import the goods, such as costs for documents, administrative fees for customs clearance and technical control, customs broker fees, terminal handling charges and inland transport.

While the data are broad in composition, they only report averages for each country's trade with all its trading partners. Data on shipping quotes provide the bilateral dimension. Limao and Venables (2001) obtain quotes for shipping a standard container from Baltimore to various destinations. The quotes are for aggregate products and based only on one city of origin, although information on the route enables the journey to be broken into sea and overland stages. Portugal-Perez & Wilson (2009) report costs of shipping a container of textiles between selected city pairs. Clarke et al (2004) use data from the U.S. Import Waterborne Databank, which covers shipments to a number of US ports, and disaggregates commodities to the six-digit HS level. Freight rates for different modes of transport can also be found in trade journals (Hummels 2001b).

The data discussed above is derived from shipping quotes or surveys. An alternative source is national customs data, which allows extraction of very detailed product information.

[7] The data are readily available at http://www.doingbusiness.org/ExploreTopics/TradingAcrossBorders/

This has the advantage of being extremely disaggregated. For example, the US Census Bureau has since 1974 made available data on US imports at the 10 digit product level by exporter country, mode of transport and district of entry. Imports are valued both inclusive and exclusive of freight and insurance charges and the discrepancy provides the measure of freight costs (see Hummels, 2001b). New Zealand has information from 1963–1997 and more recent data (since the 1990s) is available for a number of Latin American and Caribbean countries (Hummels, 2007). However, data of this type is only available for a relatively small set of countries.

A further source of data is derived from the IMF Direction of Trade Statistics (DOT), which allows comparison of data reported by the exporting country "free-on-board" (fob) with the corresponding import data reported by the importer inclusive of the costs of insurance and freight (cif). The cif/fob ratio is then taken as a measure of transport costs. On average, this ratio was 1.28 in 1990 (Limao & Venables, 2001). This data has the advantage of broad country coverage, covering up to 25000 potential bilateral trade flows, and most countries have good information from the 1980s onwards. However, problems include the fact that it is an aggregate over all commodities and so depends on the composition of trade, and that a high proportion of observations are imputed.[8]

3.2 The responsiveness of trade to transport costs

We have demonstrated large cross-country variations in transport costs in terms of time and money, but do they contribute to variations in trade?

Empirical studies have regressed trade flows on various measures of transport costs. To avoid omitted variable bias such regressions include a number of control variables, although they should only be included if they are thought to affect trade through channels other than transport costs. Dealing with variables that may work through a number of channels may be difficult. For example, including distance in such a regression would, in principle, give evidence of a relationship other than through the transport cost channel. In practice, identification is seldom so neat in econometrics, so it would be hard to be confident that some of the effects of transport costs are not being picked up also by the distance variable.

Econometric studies suggest that freight costs have a statistically significant and quantitatively important impact on trade flows. Limao and Venables (2001) use both cif/fob

[8] See Hummels (2001b) and Hummels and Lugovskyy (2006) for a discussion.

measures and freight rates and find estimates of the elasticity of trade with respect to the freight cost factor [9] in the range –2 to –3.5. The quantitative importance of freight rates is indicated by their calculation that a move from the median value to the 75th percentile in their sample cuts trade volumes by two-thirds. With a similar methodology, Clarke et al (2004) estimate an elasticity of about –1.3 for country-specific transport costs. Because shipping costs are quoted on a per unit basis, the ad valorem cost falls proportionately as the price of the good rises (or equivalently, as the weight falls), despite potentially higher handling or insurance costs. This has been used to argue that transport costs lead to the export of higher quality products (Hummels & Skiba, 2004).

3.3 The contribution of transport costs to trade growth

The studies above were based primarily on using cross-section variation to identify the impact of freight costs on trade. How important have reductions in freight costs been in driving the growth of world trade through time? Baier and Bergstrand (2001) look at the determinants of the growth of trade in the period 1958-60 to 1986-88. They use data for 16 OECD countries to find an elasticity of trade with respect to the cif/fob ratio of –3, consistent with the cross-section findings of the previous sub-section. The main contribution of Baier and Bergstrand's paper is to estimate the relative contributions of income growth, trade liberalisation, and changes in transport costs to the recorded growth of trade. Their estimates suggest that reductions in trade costs played a minor part in this growth. Income growth accounted for 66% of the growth, trade liberalisation for 26%, and lower transport costs just 8%. Combined, the 34% attributed to trade costs (ie transport costs plus trade policy restrictions) is consistent with Jacks, Meissner & Novy (2008), who attribute 31% of the 1950-2000 trade expansion to trade costs[10] and calculate a much higher proportion (55%) for the pre-World War One trade boom.

Despite estimating a similar elasticity, the results in Baier & Bergstrand (2001) suggest transport costs have a relatively minor role, yet those in Limao & Venables (2001) imply transport costs are very important. The reason for this apparent contradiction is that the cross-section variation in freight rates in the sample is large, consistent with Table 1, while transport costs did not fall very much over time. This is somewhat at odds with the popular

[9] The freight cost factor measures the impact of trade costs on the delivered price. Thus, if trade costs are 10% of the value of the product the trade cost factor is 1.1. It is natural to measure the elasticity of a trade flow with respect to this delivered cost, not the trade cost alone.

[10] They derive their measure of trade costs by comparing international trade flows with internal flows in a way that is consistent with a large number of formal gravity models. The method does not permit a further decomposition into transport and non-transport costs.

belief that transport costs have fallen in recent times and the reasoning for this is elaborated in section 4.

3.4 Transport costs and modal choice

Transport costs shape not only the volume of trade, but also the modal choice. Most goods travel by ship, but a striking development in recent years has been the growing volume of goods shipped by air. Over the period 1975-2004, manufactured goods traded by air grew by 7.4% per annum while goods traded across the ocean grew by 4.4% pa. Furthermore, planes tend to carry more valuable goods over longer distances. In volume terms, less than 1% of goods now travel by air, but more than a third of the value of goods imported by the US now arrives on planes.[11] In terms of ton-miles, the growth rate of air transport was even higher than that of other modes (Hummels, 2007).

The modal choice is primarily a trade-off between higher monetary transport costs and faster journey time. Reliability and a reduction in delivery uncertainty are particularly important for trade in intermediates or in products where demand may be transient (Harrigan & Venables, 2006). By comparing the freight costs of alternative transport modes with journey times, researchers have been able to come up with measures of the value of time saved in transit. For example, Hummels (2001a) matches shipments that are similar in all respects (commodity, country of origin, final destination) except mode of transport. If there are two matched shipments, i.e. two very similar trades going on, but one by sea and one by air, then it can be argued that shippers must be close to indifference between modes. Since the modes differ in cost and speed, shippers' choices give an implicit value of the time saved. This turns out to be extremely high, being worth as much as 0.5% of the value of goods shipped, *per day*. Taking a mean ocean voyage of 20 days and assigning one day to air travel, Hummels computes a 9% tax equivalent of time costs for the US such that the transport cost factor associated with time delays in 1.09.

Hummels & Schaur (2009) estimate the value of time saving using US import data that report the price and quantity of air shipping relative to ocean shipping as well as time delays associated with ocean shipping. The idea is that a firm's willingness to pay for more expensive air shipping is increasing in the number of days saved with airplanes and decreasing in the premium paid to ship by air. Using this approach, Hummels, Minor,

[11] The value of shipments by sea also far exceeds the value of shipments by land (Moreira, Volpe & Blyde, 2008).

Reisman & Endean (2007) calculate tariff equivalent costs of time delays and produce these by geographic region and product. For example, they calculate that avoiding a day of delay would be worth 2% of the value of a shipment of road vehicles, but only 0.2% for footwear. How does delay impact the volume of trade? Djankov et al (2006) calculate that the trade impediment of an additional day in transit reduces trade by more than 1%. Given the variations seen in Table 1, handling delays are contributing substantially to variations in trade volumes. Djankov et al calculate that, were Uganda to reduce its transit times from 58 days to the median of 27, this would be equivalent to reducing its distance from its trading partners by 2200km.

In summary, we revealed the responsiveness of trade to transport costs is large. Delay costs are of the same order of magnitude as freight costs, affecting trade volumes and the mode of transport. Because of large variations across regions, transport costs are an important factor in explaining trade patterns, but they have not necessarily contributed greatly to recent increased trade volumes.

4. The determinants of transport costs

We now shift our attention from the implications of transport costs to their determinants. In terms of equation (1), we are interested in establishing the effects of the arguments in the transport cost function, i.e. looking in detail at the relationship:

$$\textit{Transport costs} = \mathrm{f}(\textit{distance, geography, infrastructure, trade facilitation, technology, fuel costs,......}) \quad (4)$$

Once again, evidence comes from both cross-section and time-series data and we look at each in turn.

4.1 Cross-section

As noted in Table 1, there is considerable dispersion of transport costs, together with wide variations in the natural and man-made barriers between countries. What factors determine the magnitude of these cost barriers?

Distance and geography

The review in Abe & Wilson (2009) concludes that the elasticity of transport cost per unit weight with respect to port-to-port distance is between 0.14 to 0.21. The elasticity is well below unity and indicates diminishing average costs with respect to distance. The measure does not allow for whether the distance is by land or by sea. Reduced-form gravity models do not account for this distinction, but some studies of costs do. Limao & Venables (2001) find that an extra 1000km distance raises costs by seven times more if the distance is overland than if it is maritime. In Hummels (2001b), the elasticities of transport costs with respect to distance are 0.46 (air), 0.39 (rail), 0.275 (road) and 0.22 (sea). In later work, Hummels (2007) estimates that, although the distance elasticity of costs was higher by air than by sea, it has declined faster over time such that they had practically equal elasticities of 0.16 (air) and 0.15 (sea) in 2004. The summary in Abe & Wilson (2009) concludes the elasticity is higher by land than by sea, all of which suggest access to the coast is important.

Indeed, landlocked countries face a major cost disadvantage, which is important because more than a fifth of the world's countries are landlocked. According to World Bank data,[12] the world's ten highest freight costs are dominated by landlocked countries and even Switzerland ranks among the worst third of countries. Limao & Venables (2001) find that landlocked countries have transport costs that are 50% higher than other comparable countries. Some regions are disproportionately landlocked; in particular, 40% of sub-Saharan Africa's people live in landlocked countries (Ndulu, et al, 2007). For these nations, it is especially important to be able to move across land cheaply and quickly. Thus, the quality of transport infrastructure and ease of transit can be important factors.

Infrastructure and Trade Facilitation

Infrastructure investment, while costly to undertake, has a major impact in reducing transport costs. The stock of infrastructure is frequently measured by an index of road, rail and telecommunications capacity, as pioneered by Canning (1998) . Updated data is produced in the *World Development Indicators* giving the percentage of paved roads in a country. The *Global Competitiveness Report*, published by the World Economic Forum, has information on telephone density. The *Logistics Performance Index* (LPI) from the World Bank combines objective measures and the subjective opinions of logistics professionals (Arvis, Mustra, Ojala & Naula, 2007).

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[12] Taken from their *Doing Business* website at www.doingbusiness.org

To investigate the importance of infrastructure, Limao & Venables (2001) use an index based on Canning's work to calculate that variation in infrastructure accounts for 40% of the variation in predicted transport costs in coastal countries and up to 60% in landlocked countries. Improvements in road, rail and telephone infrastructure from the 25th to 75th percentile would overcome more than half the disadvantage of being landlocked.

Given that most goods travel by ship (Hummels, 2007), it is no surprise that many studies emphasise the importance of ports. Clarke et al (2004) use port efficiency measures based on an index from the *Global Competitiveness Report,* which in turn is based on business surveys.[13] According to the report, Singapore has a score of 6.8 and Bosnia-Herzegovina has a score of 1.5 on a 1-7 scale. Namibia scores highly (5.4) yet Brazil, despite being more developed, ranks 127th out of 133 countries with a score of 2.6 (World Economic Forum, 2009). Clarke et al (ibid) estimate that a deterioration in port quality from the 75th to 25th percentile raises shipping costs 12% and is like being 60% further away from markets. Because the elasticity of costs with respect to distance is well below unity (as we saw earlier), they argue the remoteness disadvantage can be overcome with well-run ports.

Infrastructure may require a lot of investment while the ability to manage shipments efficiently may require technological and managerial improvements. Ports are in part a natural phenomenon but their effectiveness is also institutional. For example, Clarke et al (2004) confirm ports are more efficient if there is less organised crime but find a non-linear relationship between efficiency and regulation, with some being better than too much or none.

Hoekman & Nicita (2008) report the fees associated with procedures to import a 20ft container average $1212 in low income countries compared to $814 in high income countries. At the same time, the LPI measure of customs clearance quality displays much greater satisfaction in rich countries than poor.[14] The LPI is based in part on perceptions but also on objective numbers like the rate of physical inspection – many countries choose to inspect 100% of the goods physically while many others inspect only 1% – and on the actual days procedures take, where the time taken between the submission of an accepted customs declaration and customs clearance is less than a day in many countries but ten days in Benin and Sierra Leone (Arvis, Mustra, Ojala & Naula (2007)). There can be many procedural impediments. For example, Djankov et al (2006) note it takes 17 procedures to export a good from Burundi, which take more than two months to complete. Burundi is far from the coast

[13] Wilson et al (2005) combine this sea port measure with a measure of airport quality.
[14] The data can be accessed at www.worldbank.org/lpi.

and needs to cross borders, but Fiji does not have this problem. Why then do exporters in Fiji need 13 signatures[15] when the French need two? Thus, while geography is important and while clearing customs can require potentially expensive technology or know-how, red tape clearly plays a role.

Teravanithorn & Raballand (2008) document a negative simple correlation between the overall LPI and transport prices, which implies a one standard deviation improvement in logistics (2/3 of a unit) would reduce the cost of truck transport by about 1 US cent per vehicle-km. Arvis, Mustra, Ojala & Naula (2007) calculate that, on average, a one-point fall in the LPI corresponds to exports taking three more days to travel from the warehouse to port. Improving Ethiopian logistics half way to South African levels is equivalent to a 7.5% tariff reduction on Ethiopian exports (Portugal-Perez & Wilson, 2009).

To summarise, transport costs are determined in part by the physical geography of distance and landlocked-ness, but also significantly by the fact that goods spend a lot of time moving slowly between borders or standing still at borders. Wilson (2003) calculates that the average time spent waiting at a border could have been used to travel 1600km in-land. This can be due to physical infrastructure deficiencies like ports but also because of procedural delays.

Market Power

So far we have considered the prices paid by users of transport in terms of the costs of supplying those services, but price-cost mark-ups also matter. While tramp shipping is set on spot markets, much liner shipping is priced by conferences, which facilitate collusion and possible exploitation of market power. According to Hummels et al (2009), one in six importer–exporter pairs world-wide was served by only one ship operating on that route. Over half were served by three or fewer ships, which in many cases were owned by a single carrier. Davies (1986) argues that, despite a market structure conducive to collusion, the general cargo market is sufficiently contestable to prevent it. In contrast, Fink, Mattoo & Neagu (2000) reveal higher prices occur where there are price fixing agreements, but this may be endogenous. Thinking of transport services as a derived demand, Hummels et al (2009) establish that transport prices are higher if there is a low elasticity of import demand and that having more shippers lowers the price and the impact of the elasticity. These two

[15] Bill of lading, Cargo release order, Certificate of origin, Commercial invoice, Consular invoice Customs export declaration, Terminal handling receipts, Export license, Foreign exchange authorization Inspection report, Packing list, Tax certificate, Technical standard/health certificate.

studies indicate the exercise of market power, which implies more competition would reduce transport charges.

It is not only ocean shipping that is subject to a lack of competition. In road transport, deregulation in France, Mexico and elsewhere has increased market entry and reduced prices (Teravanithorn & Raballand, 2008). In the US, deregulation of freight meant most truck workers stopped being represented by the Teamsters union and lost bargaining power (Belzer, 1995). Lack of effective competition is widespread in Africa, and means that ground transport prices are relatively high even though costs are not. While prices range from 6 to 11 US cents/km in Africa, they are 5 cents/km in Western Europe. Yet costs are 1.87 and 1.33 cents/km in Central and East Africa compared to 1.52 (Spain) and 1.71 (Germany) cents/km in Western Europe. The wide margin of price over cost in Africa is not due to superior service because measures of transport quality are also inferior (Teravanithorn & Raballand, 2008).

4.2 Time series

We have highlighted some factors that determine the variation in transport costs between countries and now turn to the factors that have caused them to change through time. As we saw in sections 2 and 3, there are puzzles to do with the relatively minor role of trade costs in driving the growth of trade volumes (section 3.3) and the increase in the absolute magnitude of the distance coefficient in gravity equations (section 2). To explain these, we have to look in more detail at the evolution of transport costs.

The evolution of transport costs

The second half of the twentieth century saw continuing transport innovation. Technical innovation involved containerisation and jet transport. Institutional innovation included open registry shipping (the practice of registering vessels under flags of convenience to circumvent higher regulatory and manning costs imposed by wealthier nations), open skies agreements, and other transport deregulation (Hummels, 2007). By facilitating the transfer of goods on and off ships, the costs of using a container ship are half those of a conventional ship per unit of freight, even after factoring in higher capital costs for container ships (Levinson, 2006).[16]

[16] Containerized cargo forms 70% of all trade and 90% of liner trade from developed countries. Liners operate on fixed routes and schedules and are used for non-bulk cargo. Dry bulk cargo uses co-called tramp ships, which have irregular routes and schedules (Clarke et al, 2004; UNCTAD, 2009).

Did the cost of moving goods fall? Aircraft revenue per ton-km fell from 3.87 in 1955 to 0.30 in 2004 (measured in 2000 US Dollars), with a particularly steep fall taking place after the introduction of the jet engine (Hummels, 2007). Micco & Serebrisky (2006) find that open skies agreements reduced air transport costs by 9%. While there is evidence that the price of air transport declined, the same is not true for ships. Hummels (2007) tracks the trends of ocean shipping over time. For bulk cargo, he uses US data to show that, while the price of transport fell steadily in real dollars per ton, it did not fall relative to the value of goods shipped. Bulk cargo does not use containers but liner shipping does. German data show that liner prices (deflated using the GDP deflator or a traded goods price index) rose in the 1970s and fell in the late 1980s onwards such that they have remained more or less unchanged in ad valorem terms over 50 years.

Given the dominance of shipping in trade volumes, the US and German data imply that falls in overall transportation costs have been modest. This in turn informs why transport costs have been attributed a fairly small role in the post-World War II boom in trade (as seen in section 3), but why did these technological changes not have a more dramatic effect?

The main reason appears to be input costs. Levinson (2006) reports that heavily unionized labour delayed the introduction of container shipping and reaped a share of the cost savings. For example, they negotiated additional unnecessary loading and unloading procedures to generate extra work. Workers' power diminished in the 1970s, just in time for the first oil price shock in 1973. Hummels (2007) argues the rising fuel costs had an upward effect on transport costs in the 1970s. Only after fuel costs began to moderate did transport costs fall.

This argument is supported by evidence on the contribution of fuel to costs. Fuel can comprise 40-63% of operating costs depending on ship size.[17] UNCTAD (2009) calculates the elasticity of costs with respect to fuel prices is 0.19-0.36 for containerized vessels. Transporting oil is similar but dry bulk costs are more fuel price elastic. They place their results in the context of a "rule-of-thumb" elasticity of 0.4 for bulk goods and a bit less for containerised cargo.[18] Is it possible to isolate a contribution of containers in the absence of fuel costs? Industry reports cited in Levinson (2006) attribute big savings to the container. For example, by the late 1980s, freight rates from Asia to the United States were calculated to

[17] This clearly depends on fuel costs too. For example, fuel costs rose from a quarter of operating costs to one half of operating costs between 1972 and 1974 (Levinson, 2006).
[18] A simple comparison of changes in aviation fuel prices and airline operating costs implies an elasticity of 0.48 for air transport (Hummels, 2009).

be 40-60% lower. More generally, Clarke et al (2004) find containerization is negatively associated with transport prices across countries, as do Abe & Wilson (2009).

Transport quality, the mode of production and distance.

Many of the benefits of improved transport technology accrued through reduced journey times and better reliability, as well as through lower costs. This is evident for air travel and also applies to other modes. For example, one of the main benefits of the container manifested itself as time reductions associated with ease of transfer to land transport. Maritime shipping times have also fallen; Hummels (2001a) reports that the average shipping time for routes to the US fell from 40 days to 10 days between 1950 and 1998.[19]

These changes have had important implications for the composition of trade, enabling previously non-traded goods to be traded, and allowing new production methods to be used. The clearest example of the benefits of faster shipping time has been in the growth of non-traditional agricultural exports, such as Sub-Saharan Africa's exports of cut flowers and fresh vegetables.[20] It is not only agricultural goods that are time sensitive, as we saw in our discussion of the value of time in transit in section 3.4. It also applies to manufactures, and lower transport times are one of the factors driving the increasing share of manufactures in world trade (UNIDO, 2009).

These changes have enabled new forms of manufacturing to develop. Manufacturing processes are becoming increasingly fragmented, a phenomenon that has been labeled "trade in tasks", "value-chains" or "off-shoring" (UNIDO, 2009; Grossman & Rossi-Hansberg 2008). Levinson (2006) argues this would not have been feasible without the standardized shipping container. Furthermore, the more widespread adoption of just-in-time concepts, for example the use of manufacturing's just-in-time principles in retailing (Nordås, Pinali & Geloso Grosso, 2006), has placed increased importance on the value of time and on the importance of distance.

These phenomena mean that the modest contribution of transport to the growth of world trade volumes found by Baier and Bergstrand (2001) and discussed in section 3.3 underplays the impact of transport improvements on trade. Transport improvements have had a much more significant impact on trade – and the organization of production more widely – than is captured in their measure of trade costs.

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[19] However, high oil prices lead to the production of more fuel efficient but slower ships (Levinson, 2006).

[20] Djankov et al (2006) estimate that a day's delay reduces a country's relative exports of time-sensitive to time-insensitive agricultural goods by six percent.

They also explain the puzzle that trade has become more local. Time-sensitive products can now be traded internationally, but often this trade is with nearby countries to minimize both the length and the possible variance of journey times. Evans & Harrigan (2005) find that, if timely delivery is important, the goods will be produced near the source of final demand. For example, US apparel imports that are susceptible to fashion trends and whose popularity is unpredictable are being increasingly imported from nearby countries. Thus, the World Bank argues that lower transport costs are *increasing* the regionalization of trade so that distance is more important than before (2009).

5. Methodological issues

The studies that we have discussed provide insights into the determinants of transport costs and their role in determining overall volumes of trade. However, there are numerous unsolved problems in the literature, some of them methodological. Gravity models have received particular study with, for example, Anderson & van Wincoop (2004) discussing empirical issues and Disdier & Head (2008) using meta analysis to investigate how they may impact the results. We discuss two of these issues.

5.1 Third country effects and zeroes

Equation (2) models a bilateral trade flow between two countries. One set of issues in gravity modelling stems from the importance of third-country effects on the one-hand and from the large number of cases where there are no bilateral trade flows on the other.

Properly grounded gravity models incorporate the fact that demand for a product depends on its price relative to that of other products. Therefore, the trade response to a reduction in transport costs between a pair of countries depends on changes in transport costs elsewhere. This is the intuition behind "multilateral resistance", a term coined and modelled by Anderson & van Wincoop (2003, 2004). This work, which is frequently cited by empirical researchers, dictates that there should be terms controlling for these third country effects; in other words, there should be controls for transport costs other than in the importer-exporter pair. Despite frequent citation, two of the paper's key messages are often ignored. First, omitting such controls can lead to biased estimates, for example of the distance coefficient τ_1 in Section 2. The use of importer and exporter fixed effects can resolve the estimation issues. Second, even with τ_1 correctly estimated, the terms representing the third country effects are hidden in the fixed effects, so the trade response based only on τ_1 is still mis-calculated.

Dealing with these effects fully required solving a non-linear system of prices, which may be why almost no empirical studies did so. However, a recent contribution by Baier & Bergstrand (2009) allows one to take account of these effects using easily-constructed controls such that one can continue to estimate a single gravity equation by OLS *and* conduct comparative statics including third country effects. We expect many future empirical gravity models to do so.

The gravity literature has also renewed its attention on the prevalence of zeros in international trade, which typically comprises half the world's bilateral trade pairs. One therefore needs to distinguish between effects which condition on countries already trading and effects which open new trade partnerships. Francois, Kepler & Manchin (2007) investigate the latter. However, even if one is interested in estimating the former using a specification like equation 2, the existence of zeros can be problematic due to sample selection issues (Coe & Hoffmaister, 1999; Santos Silva & Tenreyro, 2006).

A recent theoretical explanation for zeroes is based on the heterogeneous productivities of exporting firms. As noted in Bernard, Jensen, Redding & Schott (2007), a relatively small proportion of firms export. Helpman, Melitz & Rubinstein (2008) develop a two-step method which accounts for zeros and firm heterogeneity using the argument that only the more productive firms will find it sufficiently profitable to cover the fixed costs of exporting to a destination. In the first step, they estimate a probit model for bilateral country-level exports, which they use to construct controls for zeros and for the proportion of firms selling from the exporter to the importer. They then add these controls to the otherwise standard gravity model. Behar & Nelson (2009) find that ignoring this factor leads to an underestimate of the effects of trade costs on trade for the average country.

5.2 Endogeneity and non-linearities

A significant coefficient in equation (2) is usually interpreted as a causal effect of, say, infrastructure on trade. Yet many explanatory variables can be endogenous. For example, increased trade can reduce the ease of transit and increase transport cost; as trade volumes surged in China, the average wait time at Shanghai's port expanded by two days in 2003 (Djankov et al, 2006). Abe & Wilson (2009) find evidence that congested ports indeed generate higher costs. In contrast, it may be that higher trade volumes stimulate the construction of new infrastructure and the introduction of more efficient clearance technologies: the marginal value of investments in trade facilitating measures may be higher if exports are high, while some aspects of the logistics technology are subject to scale economies and thus only worthwhile at very high volumes. Djankov et al (2006) note that, as a result of the added congestion, Shanghai added 12 loading berths in 2004. Hummels & Skiba (2004) find evidence that trade affected the timing of containerization and Levinson (2006:233) quotes that "If ever there was a business in which economies of scale mattered, container shipping was it." From an empirical perspective, the congestion argument implies an underestimate of the gravity model coefficients while the increasing-returns argument implies an overestimate. A standard approach to dealing with endogeneity bias is the use of instrumental variables.[21] However, as in many applications, finding suitable instruments can be difficult.

Other important factors are potential trade-imbalances, which limit the scope for splitting fixed costs over two journeys but which may provide cheap prices to those exploiting spare capacity on the return journey. For example, US exporters to the Caribbean pay 83% more than US importers because the ship is 72% empty on the way to the US (Furchsluger, 2000). Having a full ship on one or both legs reduces costs. Having a big ship also reduces costs. For example, access to Buenos Aires costs $70 per container for a 200 TEU vessel but only $14 for 1000 TEU one (Clarke et al, 2004). However, the additional fixed cost of a bigger vessel only becomes worthwhile at a certain level of trade. Furthermore, the process of moving goods is inherently subject to non-linearities and bottlenecks. For example, a major road upgrading program will have a limited impact on costs and time if the port is full or the border is closed. Although one may try to approximate such features by interacting the variables, they may not accurately capture the inherent non-linearities.

This section has highlighted some issues that may impede the accurate estimation of the coefficients in the gravity model and may lead to incorrect calculation of the effects of transport costs on trade. Nonetheless, taking it as given that the coefficients have been accurately estimated and that the trade effects have been properly calculated, what are the broader implications?

6. Conclusions

Transport costs affect international trade and vice versa. Both are influenced by considerations of geography, technology, infrastructure, fuel costs and policy towards trade

[21] See for example chapter 5 in Wooldridge (2002)

facilitation. Researchers have sought both to quantify reduced form relationships and to explore the channels through which they operate. Our synthesis of these relationships is given in equation (1) and we return to it to pull results together. For example, consider the effect of distance on trade. Expressed in elasticity form, we could write

$$\frac{\Delta Trade}{\Delta Dist}\times\frac{Dist}{Trade}=\left(\frac{\partial Trade}{\partial Cost}\times\frac{Cost}{Trade}\right)\times\left(\frac{\Delta Cost}{\Delta Dist}\times\frac{Dist}{Cost}\right)+\frac{\partial Trade}{\partial Dist}\times\frac{Dist}{Trade}$$

$$\begin{array}{ccccc} -0.9 & \quad -3.0 & \quad 0.2 & \quad ? & \quad (5) \end{array}$$

The left hand side gives the overall (or reduced form) effect of distance on trade, while the right hand side decomposes it into a part associated with freight costs and a residual. The gravity model estimates reviewed in section 2 indicate a consensus reduced-form elasticity of trade with respect to distance of -0.9. In section 3, we found that the elasticity of trade with respect to the freight cost factor is of the order -3. Estimates of the elasticity of freight costs with respect to distance were reviewed in section 4; they vary greatly across mode, but a summary order of magnitude is 0.2. The relationship above suggests freight costs account for two thirds of the effect of distance (0.2*-3 = - 0.6). The remaining third could be accounted for by delays - although the relationship between distance and time is highly non-linear due to its effect on modal choice - and the effect of distance through channels other than freight costs, such as cultural or language proximity.

Distance is not the only important geographical factor. Being landlocked increases trade costs by 50% and reduces trade volumes by 30-60%, numbers that are broadly consistent with the elasticity of trade with respect to costs given above. Geography is not the only determinant and the hard and soft infrastructure of transport can offset the geographical disadvantage faced by some countries. Over time, technical change and the price of fuel have influenced transport costs and trade volumes. In the case of fuel costs, it is reasonable to assume the effect on trade is exclusively through the freight cost channel. Therefore, we can use the rule-of-thumb relationship of -0.4 in section 4 to calculate an elasticity of trade with respect to fuel costs of 0.4*-3 = -1.2.

While historical studies suggest that the contribution of falling trade costs to the growth of trade is smaller than might have been expected, the puzzle is resolved by the fact that the measured fall in trade costs is quite low. Looking back, there are several reasons for this. One is the continuing importance of fuel costs. A second is that it is the fall in trade costs relative to the value of goods shipped that is the key variable, and it is not obvious that technical advance in transport has been consistently more rapid that technical progress in other areas. Finally, much of the technical advance in transport has gone into improved quality (speed and reliability) rather than lower cost.

Some aspects of the change in quality of transport services have been widely researched. We saw that time in transit is valuable and that transport times have fallen. This has affected trade volumes, but the full impact of these changes is broader. Quicker transport has allowed new time-sensitive products to be traded internationally – be it agricultural goods from Africa or fashion sensitive goods from Asia. They are also transforming the patterns of world production as just-in-time and similar management techniques come to be operated on an international level through production networks.

Finally, what are the implications of transport costs for growth and development, and what policy messages follow? We have found evidence of measures that can reduce transport costs and hence stimulate trade. Does it naturally follow that such measures should be undertaken? The gains from trade have been extensively, if controversially, researched. Measures of openness have been used as a variable in cross-country growth regressions. For example, Frankel & Romer (1999) use a gravity model to instrument for trade flows and in turn use this to argue that trade has a large and robust, albeit moderately statistically significant, causal impact on growth.[22] A more structural approach is presented in Redding & Venables (2004), who emphasise the effect of remoteness and other trade costs on per capita income through the trade channel. Remote economies are disadvantaged through two mechanisms. One is that imports – including essential imports such as fuel and capital equipment – are relatively expensive. The other is that such locations face cost hurdles in exporting, and are consequently unattractive to investors looking for locations in which to produce and export. Redding & Venables formalise these ideas in the concepts of supplier access and market access and show these measures are important determinants of countries' levels of income.

On the other side of the policy choice, are the costs incurred in infrastructure or other investments. Cost-benefit analysis is widely used on a project by project basis. The wider – and more international – the project, the harder it is to make such calculations. An example is that of Buys, Deichmann & Wheeler (2006), who calculate that a programme of road network expansion in Africa would increase trade by $250 billion over 15 years and cost the project at $20 billion plus $1 billion per year. Trade does not map directly to benefits, but a

[22] In many applications, the use of instruments leads to larger standard errors and hence lower significance levels.

bolder calculation is offered by Abe & Wilson (2009). They find that transport cost reductions from investments in East Asian port infrastructure would generate $8 million of consumer surplus per year and cost less than $3 million per year. In principle, regulatory reforms such as reducing the number of documents required to export should be cheap to implement and some suggest that trade facilitation of this sort is "low hanging fruit" (Nordas et al, 2006). However, this naively ignores the political elements behind them; for example allocating someone a procedural post is a source of patronage. Furthermore, developing countries may lack the technical expertise required to implement new systems.[23]

Additionally there are, in the nature of international trade, cross-country externalities and complementarities. For example, we saw that landlocked countries' transport costs and trade volumes are highly dependent on their neighbours' policies. In the case of trade policy, the WTO exists to internalise such effects. For transport investments, arrangements are more ad hoc, falling to bilateral or plurilateral cooperation between countries supplemented by supra-national bodies such as the European Union, or the funding and technical assistance of the development banks. For example, the UN sponsored "Almaty Programme" is aimed at relieving some of the difficulties faced by landlocked countries. Goals include recognizing freedom of transit, developing regional transport infrastructure and fostering transnational co-operation (Arvis, Raballiland & Marteau, 2007). The World Bank emphasises the importance of regional infrastructure projects and broader trade facilitation measures (World Bank, 2009). The work surveyed in this chapter suggests such initiatives will help reduce transport costs and boost trade volumes for many countries and their neighbours.

[23] For a further discussion, see Engman (2005).

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