**Measures of Globalization in a World with Fragmented Production**

**Bart Los and Umed Temurshoev**

University of Groningen, Faculty of Economics and Business;

[b.los@rug.nl](mailto:b.los@rug.nl), u.temurshoev@rug.nl

This version: May 20, 2012

**Preliminary and incomplete, please do not quote**

Abstract

Despite the widespread impression that improvements in communication technology and reductions in transportation costs should have led to more trade between distant countries, the empirical literature did not find anything that shows a tendency towards “the death of distance”. In this paper, we investigate whether this is due to the implicit assumption in these studies that international trade relates to final goods only. We propose a simple but versatile method to estimate the expected distance a product will travel before it will end up somewhere as a consumption or investment good, after having gone through internationally fragmented production chains. The method is empirically applied using a time series of “World Input-Output Tables”, constructed by the World Input-Output Database (WIOD) consortium for the period 1995-2009. Our indicator shows that distances travelled by products have generally increased significantly.

Keywords: Distance; Globalization; Input-output tables.

*Acknowledgement*: This paper is part of the World Input-Output Database (WIOD) project funded by the European Commission, Research Directorate General as part of the 7th Framework Programme, Theme 8: Socio-Economic Sciences and Humanities, grant Agreement no: 225 281. More information on the WIOD-project can be found at [www.wiod.org](http://www.wiod.org).

We thank Erik Dietzenbacher and Marcel Timmer for comments on an earlier version of this paper.

**1. Introduction**

Until about twenty years ago, North Sea shrimps consumed by Dutch consumers were mostly caught by Dutch trawlers, peeled by Dutch housewives and elderly people and processed in Dutch food-producing companies. The product never crossed a border. Nowadays, Dutch consumers still eat the same type of shrimps, but not after the animals caught by Dutch fishermen have been transported to Africa to be peeled by Moroccan workers and have been transported back to be manufactured and consumed in The Netherlands. The peeling activities have been outsourced by the leading Dutch companies in this industry to Morocco, because labor and environmental regulations are less strict than in the home country.[[1]](#footnote-1) Apparently, transport costs are sufficiently low to make the 2x1500 km journey required to peel shrimps in Morocco rather than in The Netherlands more profitable. Distance did not really matter anymore.

This is a less known example of changes in recent decades that led authors like Cairncross (1997) to claim that distance is dead, or at least passing away. Surprisingly, most of the contributions to the empirical literature fail to find evidence for a declining importance of distance, a phenomenon that has been termed “the distance puzzle” or the “missing globalization puzzle (Coe et al., 2007; Carrère et al., 2012). The puzzle emerged in two types of analysis. First, regressions were run that link bilateral trade flows to the size of the two economies concerned, the distance between them and quite often a number of control variables. If the estimated regression coefficient for the distance variable is negative, distance can be considered to hamper trade. Disdier and Head (2008) produced a meta-analysis of empirical studies estimating these “gravity equations” and concluded that the estimated negative distance elasticities were not closer to zero for studies using recent samples than for studies considering periods in the more distant past.[[2]](#footnote-2) Second, Carrere and Schiff (2005) and Berthelon and Freund (2008) estimated an “average distance of trade” (ADOT), by taking bilateral trade-volume weighted averages of distances between a large set of country pairs. If trade volumes between countries located far apart would increase faster than volumes between nearby countries, ADOTs would increase over time. Such increases were not observed, however.

The distance puzzle might imply that Cairncross and his followers are wrong. In the international business literature, the advantages of “near-shoring” (relocating stages of production processes to nearby countries, either via FDI or via contracts with foreign suppliers) over “far-shoring” (relocating activities to distant countries) have recently been stressed (see Carmel and Abbott, 2007). Such advantages often relate to beneficial effects of shared languages, similarity of cultures and similarity of tastes. If such factors would be as strong as the favorable effects associated with far-shoring, distance might prove to remain important and the distance puzzle might not be relevant anymore.

The distance puzzle might also be a consequence of analytical flaws. In a recent paper, Carrère et al. (2012) study three potential sources of error in the gravity equation approach: (1) composition of trade effects (distance might matter more for some products than for others, so changes in the composition might lead to changes in the results for aggregates); (2) ignoring zero trade flows (if countries do not trade, this is an observation that tells something about the impact of distance and thus should be taken into account); and (3) omitted variables. Carrère et al. (2012) find evidence that corrections for these problems cannot make the puzzle vanish.

In this study, however, we argue that distance has actually become less important, over the pre-crisis period 1995-2008. We hypothesize that the two approaches that led to the distance puzzle both suffered from a problem that make them fail to take cases such as the nowadays internationally fragmented production process of shrimps properly into account. This is due to the negligence of what we might call “no-shoring”: both the gravity equation approach and the average distance of trade approach do not incorporate intra-country transactions, as a consequence of which the zero-distance traditional production process for consumable shrimps does not enter the comparison with the modern fragmented format of the production chain. In more general terms, the gravity equation approach suffers from a selection bias that excludes all zero-distance observations from the samples, while the average distance of trade approach only computes averages over nonzero distances. As a consequence, a Dutch firm relocating domestic parts of its components production to very nearby Belgium could actually lower the ADOT of imports to The Netherlands.

Using a recently developed time series of international input-output tables (Erumban et al., 2012), we develop and empirically implement a new indicator of distance, the Expected Distance to Final Destination (EDFD). It has two important advantages over existing methods. First, it explicitly integrates domestic and international trade flows. Second, it explicitly acknowledges the international fragmentation of production processes, by considering all transactions that a product goes through (as an intermediate input) before it is sold as a capital good or consumption good and reaches its final destination. Our EDFD-indicators are increasing over time, thereby solving the distance puzzle.

**2. Distance Computations**

We start our exposition by means of a simplified example. We assume that the world consists of two countries (A and B), each of which produces just one commodity. These commodities can serve as intermediate inputs (at home and abroad), but can also be consumed (at home and abroad). The world input-output table (WIOT) in such a context looks like Figure 1.

**Figure 1. Stylized world input-output table**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | A | B | A-CON | B-CON | Output |
| A | *z*AA | *z*AB | *f*AA | *f*AB | *x*A |
| B | *z*BA | *z*BB | *f*BA | *f*BB | *x*B |
| Value added | *v*A | *v*B |  |  |  |
| Output | *x*A | *x*B |  |  |  |

The first and second subscripts refer to the selling country and the purchasing country, respectively. The symbol *z* stands for deliveries for intermediate input purposes, while *f* indicates deliveries of final products (which can be consumed or be used as investment goods in the purchasing country). Since we assume that the world is composed of just A and B, these countries neither import from a Rest of the World, nor do they export to entities outside this system.

The WIOT in Figure 1 gives the values of transactions. Let us denote the share of output of country *i* used as an intermediate input in country *j* by and the corresponding share used for final demand purposes by country *j* as . Note that, by construction, for all *i*, hence the coefficients and can be interpreted as probabilities.[[3]](#footnote-3) In particular, if we consider these flows in “per dollar”-terms, it is clear that a certain product produced by A has a chance of to be used as an intermediate input in the same country. In a similar vein, the probability that it will be sold as a final product in the country itself amounts to . These transactions do not involve the crossing of national borders. There is also a chance that this product produced by A is traded to country B, either as an intermediate product or as a final product . In these cases, the product travels some distance.[[4]](#footnote-4) This distance is captured in a symmetric matrix **D**:

It will appear to be convenient to represent the probabilities that a product ends up in a given state by means of two matrices and with typical elements and , respectively.[[5]](#footnote-5) **B***I* contains the probabilities that a product will be used as an intermediate input in the next stage of the production process, while the elements of **B***F* give the probabilities that a product will leave the production process as a final product in the next stage.

In the first production stage, the *expected distance* to be traveled by a randomly drawn unit of A’s output will now equal . The equivalent expression in terms of matrices for the two countries in our hypothetical example can be compactly written as

, (1)

where is the vector of the expected distances travelled in round 1 of the production system, **u** is a summation vector of appropriate length consisting of ones, and the symbol indicates element-by-element (Hadamard) multiplication. The first term inside parentheses relates to the distance over which intermediate inputs travel, while the second term relates to distances related to final products.

After the completion of the first round, part of the unit of A’s product will have ended up with consumers (or as a capital good in a firm) and will not be moved anymore, since they left the production system. Other parts of this unit will enter a next round of production, however, because they will be used an intermediate input. The expression for these amounts is . The first term gives the intermediate inputs used in A, while the second term represents the intermediate inputs to be used in B.

In round 2 of the global production process, the parts of the A’s original unit of product that are still in the production process, again have a chance to be exported and hence to be transported over the distance *d*12 (=*d*21). The expected distance covered by these products amounts to

. (2)

The first part of this equation deals with the distance for the fraction of product that stayed as an intermediate input in country A during the first round, , which will again stay in country A in the second round of production with probability (involving zero distance) and with probability it will be exported to country B as intermediate or final product, thus travelling distance . The second part of Equation 2 addresses the distance in round two for that fraction of products that were exported as intermediates to B in the first round, . Note that part of this fraction will be exported to A again, after having gone through just one production stage in B. In matrix notation, the vector of expected distances travelled in the second stage of production is

. (3)

Next, note that the vector of fractions of the original unit of A’s (resp. B’s) product that are still in the production system, either in A or in B, after round two is equal to the first (resp. second) row of the matrix . The approach sketched for stages one and two of the fragmented production process can be repeated more often. As long as both countries deliver nonzero fractions of their outputs as final products, the proportion of the unit of A’s output that goes into the next round will decrease and finally tend towards zero. Given that the distance matrix **D** is constant over rounds, the distance traveled by the remaining intermediate inputs will also tend towards zero with the rounds of production.

By adding distances covered in each of the rounds, we arrive at the vector of total expected distance **d**:

.(4)

The matrix algebra contained in Equation 4 allows for straightforward extensions towards more realistic representations of the world, with multiple countries (1, …, *C*) and/or multiple industries (1, …, *N*). The matrices **B***I* (of dimensions *NC*x*NC*) and **B***F* (of dimensions *NC*X*C*) can be obtained directly from full intercountry input-output tables by dividing the cell values of the intermediate input block and the matrix with final demand, respectively, by output of the delivering industries. This also calls for the redefinition of the distance matrix **D** in Equation 4. It is easy to find that the vector of total expected distances for the realistic representation of the world is given by

,(5)

where and with and being, respectively, the *N*-square matrix of ones and the *N*-dimensional summation vector of ones, and the symbol indicating the Kronecker product. That is, the distance matrices (of dimension *NC*x*NC*) and (of dimension *NC*x*C*) are simple extensions of **D** to account for the fact that countries do not produce only one product as in our hypothetical example illustrated in Figure 1, but produce a variety of products represented by *N* industries in each country.[[6]](#footnote-6)

We call the *ij*-th element of the matrix as product *i*'s *total production fragmentation intensity* of the original distance of a unit of product *j*. To see this interpretation, observe from Equation 1 that the expressions following in Equations 4 and 5 are nothing else as the first production stage expected distances, thus

.(6)

If we define , then from Equation 6 it follows that . That is, in order to fully take into account production fragmentation across countries in counting the total distance traveled by product *i* as related to the distance traveled by a unit of product *j*, the first round production distance of product *j*, , has to be weighted by the corresponding fragmentation factor . Correspondingly, we also call **G** the total production fragmentation intensity matrix.

**3. Data**

***3.1 International Input-Output Tables***

In this section we outline the basic concepts and construction of our world input-output tables.[[7]](#footnote-7) Basically, a world input-output table (WIOT) is a combination of national input-output tables in which the use of products is broken down according to their origin. In contrast to the national input-output tables, this information is made explicit in the WIOT.

As building blocks for the WIOT, we will use national supply and use tables (SUTs) that are the core statistical sources from which NSIs derive national input-output tables. In short, we derive time series of national SUTs. Benchmark national SUTs are linked over time through the use of the most recent National Accounts statistics on final demand categories, and gross output and value added by detailed industry. This ensures both intercountry and intertemporal consistency of the tables. As such the WIOT is built according to the conventions of the System of National Accounts and obeys various important accounting identities. National SUTs are linked these across countries through detailed international trade statistics to create so-called international SUTs. This is based on a classification of bilateral import flows by end-use category (intermediate, consumer or investment), intermediate inputs are split by country of origin. These international SUTs are used to construct the symmetric world input-output tables. The construction of our WIOT has a number of distinct characteristics.

We rely on national supply and use tables (SUTs) rather than on input-output tables as our basic building blocks. SUTs are a natural starting point for this type of analysis as they provide information on both products and industries. A supply table provides information on products produced by each domestic industry and a use table indicates the use of each product by an industry or final user. The linking with international trade data, that is product based, and factor use that is industry-based, can be naturally made in a SUT framework.[[8]](#footnote-8)

To ensure meaningful analysis over time, we start from industry output and final consumption series given in the national accounts and benchmark national SUTs to these time-consistent series. Typically, SUTs are only available for a limited set of years (e.g. every 5 year)[[9]](#footnote-9) and once released by the national statistical institute revisions are rare. This compromises the consistency and comparability of these tables over time as statistical systems develop, new methodologies and accounting rules are used, classification schemes change and new data becomes available. By benchmarking the SUTs on consistent time series from the National Accounting System (NAS), tables can be linked over time in a meaningful way. This is done by using a SUT updating method (the SUT-RAS method) as described in Temurshoev and Timmer (2011) which is akin to the well-known bi-proportional (RAS) updating method for input-output tables. For this updating data on gross output and value added by industry is used, alongside data on final expenditure categories from the National Accounts.

Ideally, we would like to use official data on the destination of imported goods and services. But in most countries these flows are not tracked by statistical agencies. Nevertheless, most do publish an import IO table constructed with the import proportionality assumption, applying a product’s economy-wide import share for all use categories. For the US it has been found that this assumption can be rather misleading in particular at the industry-level (Feenstra and Jensen, 2009; Strassner, Yuskavage and Lee, 2009). Therefore we are not using the official import matrices but use detailed trade data to make a split. Our basic data is bilateral import flows of all countries covered in WIOD from all partners in the world at the HS6-digit product level taken from the UN COMTRADE database. Based on the detailed description products are allocated to three use categories: intermediates, final consumption, and investment, effectively extending the UN Broad Economic Categories (BEC) classification. We find that import proportions differ widely across use categories and importantly, also across country of origin. For example, imports by the Czech car industry from Germany contain a much higher share of intermediates than imports from Japan. This type of information is reflected in our WIOT by using detailed bilateral trade data. The domestic use matrix is derived as total use minus imports.

Another novel element in the WIOT is the use of data on trade in services. As yet no standardised database on bilateral service flows exists. These have been collected from various sources (including OECD, Eurostat, IMF and WTO), checked for consistence and integrated into a bilateral service trade database (see Stehrer et al., 2010, for details). Although the maximum of existing information is used, there are clear gaps in our knowledge at lower levels of aggregation.

Based on the national SUTs, National account series and international trade data, international SUTs are prepared for each country. As a final step, international SUTs are transformed into an industry-by-industry type world input-output table. We use the so-called “fixed product-sales structure” assumption stating that each product has its own specific sales structure irrespective of the industry where it is produced (see e.g. Eurostat, 2008). For a more elaborate discussion of construction methods, practical implementation and detailed sources of the WIOT, see Timmer et al. (2012).

***3.2 Distances***

We first collected data on population and geographical latitudes and longitudes for four largest cities of forty WIOD countries from <http://www.geonames.org/>. Then we computed the greatest-circle distances between all the cities using the corresponding formula from spherical geometry, where we use the ellipsoidal quadratic mean of 6372.8 km as a spherical approximation of the radius of Earth. Based on the derived distances we then obtained the intra- and inter-country distances as follows. For the intra-country distances, there are six combinations of distinct pairs of cities, hence six distances that need to be somehow aggregated into a scalar. We take the weighted average of these distances as an estimate of the concerned intra-country distance, where the corresponding population sizes are considered as weights. To clarify, assume that the four cities of country X are A, B, C and D. Let us denote the distance between country/city *i* and *j* by *dij*and the population size of city *i* by *pi*. The intra-country distance of country X is then derived from

,

where . In case of an intercountry distance, there are 16 combinations of distinct pairs of cities to be considered, hence the distance between country X and Y is derived from

,

where and are, respectively, the *i*-th cities of country X and Y, and .[[10]](#footnote-10)

Finally, we used conservative estimates of the distances of the forty WIOD countries to the Rest of the World (RoW). These are the distances between the capital cities of the WIOD countries and the capitals of the most nearby non-WIOD countries (e.g. for France, the distance to RoW equals the distance between Paris and Bern, in Switzerland)). Further, we set the intra-RoW distance to zero. We have deliberately chosen these most conservative estimates of distances to and within the RoW, because the RoW consists of geographically very diverse countries for which it is, in general, quite difficult to come up with any reasonable distance estimates and we do not want our results to be driven by large (but uncertain) values of the corresponding distances.

**4. Results: Distance is Dying (Although Slowly)!**

***4.1 Aggregate Results***

**Figure 2: Expected Distance to Final Destination (all products, all countries, in km)**

**Figure 3: Expected Distance to Final Destination, with positive intracountry distances (all products, all countries, 1995=1)**

****

***4.2 Results by Product***

**Figure 4: Differences in Expected Distance to Final Destination between products (all countries, in km)**

****

***4.3 Results by Country***

**Table 1:** Expected Distance to Final Destination (top-10 countries), 1995 - 2008)

Between 1995 and 2008, EDFD decreased for just 6 (out of 40) countries. These countries are all small countries, with one major exception. For all UK products taken together (average weighted by gross output levels), EDFD was reduced by 2.2%.

**5. Conclusions**

In this paper, we propose an indicator of globalization that explicitly recognizes that the world economy is increasingly characterized by global value chains, which involve lots of trade in intermediate inputs. We show that the introduction of this measure (“Expected Distance to Final Destination, EDFD”) solves the well-known distance puzzle. Unlike international trade statistics on which the studies leading to the distance puzzle have been based, our EDFD-measure also uses information on trade within countries. We argue that these trade flows should be considered as potential international trade flows. Our indicator applied to world input-output tables constructed in the World Input-Output Database project suggests that the share of these domestic trade flows in total trade flows decrease. Even if we do not consider countries as points (which implies that domestic trade flows do not cover any distance) but adopt an intra-country distance measure, we find that globalization leads to trade over larger distances. We do not claim that distance is dead or almost dead, but we find that it is not as healthy as thought by those who think there is a distance puzzle.

The results we obtain are not at odds with Carrère and Schiff (2005) and other studies that find a more or less stable average distance of trade. Conditional on a product being exported, we also find that products are not traded over longer distances than before. Since increasing fractions of potentially internationally traded products are actually traded internationally nowadays, and international trade covers longer distances than intra-country trade (at least on average), we feel the distance puzzle has vanished. This is a result we find for all types of products, although globalization in services (taken as a broad sector) has yielded a rate of growth for EDFD that is much lower than for natural resources and manufacturing products.

**References (to be completed)**

Arndt and Kierzkowsi (eds.), Oxford UP Volume

Berthelon, Matias and Caroline Freund (2008), On the Conservation of Distance in International Trade. *Journal of International Economics*, 75(2), 310-320.

Brun, Jean-Francois, Céline Carrère, Patrick Guillaumont and Jaime de Melo (2005), Has Distance Died? Evidence from a Panel Gravity Model. *World Bank Economic Review*, 19(1), 99-120.

Cairncross, Frances (1997) *The Death of Distance: How the Communications Revolution Will Change Our Lives* (London: Orion Publishing).

Carmel, Erran, and Pamela Abbott (2007) Why ‘Nearshore’ Means that Distance Matters. *Communications of the ACM*, 50(10), 40-46.

Carrère, Céline, Jaime de Melo and John Wilson (2012) The Distance Puzzle and Low-Income Countries: An Update. *Journal of Economic Surveys* (forthcoming).

Carrère, Céline and Maurice Schiff (2005), On the Geography of Trade: Distance is Alive and Well. *Revue Économique*, 56, 1249-1274.

Chen, Natalie (2004) *Journal of International Economics*

Coe, David T., Arvind Subramanian and Natalia T. Tamirisa (2007), The Missing Globalization Puzzle: Evidence of the Declining Importance of Distance. *IMF Staff Papers*, 54(1), 34-58.

Dietzenbacher, Erik and Isidoro Romero (2007) Production Chains in an Interregional Framework: Identification by Means of Average Propagation Lengths. *International Regional Science Review*, 30, 362-383.

Defourny, Jacques and Erik Thorbecke (1984) Structural Path Analysis and Multiplier Decomposition within a Social Accounting Matrix Framework. *Economic Journal*, 94, 111-136.

Disdier, Anne-Célia and Keith Head (2008), The Puzzling Persistence of the Distance Effect on Bilateral Trade. *Review of Economics and Statistics*, 90(1), 37-41.

Feenstra and Jensen (2009)

Ghosh, A. (1958) *Economica*

Johnson and Noguera (2012), *Journal of International Economics*.

Los, Bart, Marcel P. Timmer and Gaaitzen de Vries (2012) Job Dynamics and Global Supply Chains. Preliminary paper presented at the Penn World Tables Workshop, Philadelphia, May 2012.

Strassner, Eric, Yuskavage and Lee (2009)

Temurshoev, Umed and Marcel P. Timmer (2011) *Papers in Regional Science*

Timmer, Marcel P. (ed.) (2012) “The World Input-Output Database (WIOD): Contents, Sources and Methods”. Document available at

<http://www.wiod.org/publications/source_docs/WIOD_sources.pdf>.

1. See http://www.heiploeg.nl/noordzee-garnalen.en\_US.html for statements by one of the market leaders about the decision to outsource. [↑](#footnote-ref-1)
2. See also Berthelon and Freund (2008). [↑](#footnote-ref-2)
3. This interpretation is valid as long as . [↑](#footnote-ref-3)
4. Deliveries within a country will most likely also entail transport of the product involved. Since the type of dataset that we will deploy for our empirical analysis does not include information on the centers of activity by industry, we will consider countries as points. Consequently, distances within countries are assumed to be zero, while distances between countries are positive. [↑](#footnote-ref-4)
5. These probabilities could also have been included in a single matrix, which would have been a square Markov transition probabilities matrix. The probabilities that a final product would be transformed into an intermediate input or a final product abroad should in such a context be set equal to zero, implying that final products in A and B would be two absorbing states. For our purposes, a representation with two probabilities matrices is more useful. [↑](#footnote-ref-5)
6. Our approach bears some similarity to the structural path analyses proposed by Defourny and Thorbecke (1984) and the average propagation length concept introduced by Dietzenbacher and Romero (2007). [↑](#footnote-ref-6)
7. The current version of this section is virtually identical to parts of Section 4 of Los et al. (2012). [↑](#footnote-ref-7)
8. As industries also have secondary production a simple mapping of industries and products is not feasible. [↑](#footnote-ref-8)
9. Though recently, most countries in the European Union have moved to the publication of annual SUTs. [↑](#footnote-ref-9)
10. See e.g. Chan (2004) for alternative approaches to estimating distances within countries. [↑](#footnote-ref-10)