

Proximity and Production Fragmentation[†]

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Recent decades have seen an acceleration in cross-border production fragmentation, defined by specialization across vertically linked stages of the production process. In practice, this means that countries import intermediate inputs, combine those inputs with domestic value added, and reexport the combined product either as a final good or as an input into later production stages.

These fragmented production processes are commonly referred to as “global” production chains. Anecdotes suggest, however, that many of these chains might be more accurately described as “local” production chains, since they include geographically proximate countries. For example, auto parts trade is concentrated *within* North America, while production and assembly of electronic components occurs *within* Asia. And for good reason, too: proximity conserves on trade costs that are incurred based on the distance gross shipments travel between production stages. Further, regional trade integration initiatives have lowered trade barriers preferentially among nearby countries.

Building on this logic, one might expect to see increases in production fragmentation over time concentrated among proximate trading partners. This in turn implies that fragmentation may be driving localization in trade over time. In this paper, we present evidence supporting both of these conjectures.

To measure changes in fragmentation, we draw on new data developed in Johnson and Noguera (2012a) that measures trade in gross and value added terms over the past four decades. Comparing gross and value added trade sheds light on fragmented production chains because

these chains give rise to double counting in trade statistics. This double counting implies that gross trade is a multiple of the actual amount of value added exchanged between countries. Changes in the magnitude of this double counting then serve as a measure of changes in fragmentation.

We present three results documenting how changes in fragmentation are related to proximity. First, we show that value added to export ratios are lower and are falling more rapidly over time among partners within geographic regions than among partners split across regions. Second, we show that the weighted average distance from source to destination is lower for gross trade than trade in value added, and this discrepancy is growing over time. Put differently, gross trade increasingly travels shorter distances than value added trade, consistent with fragmentation serving to localize trade. Third, we show that bilateral value added to export ratios have fallen more among nearby trading partners, due to the fact that gross trade has increased most among proximate trade partners.

I. Measuring Value Added Trade through Time

To measure the value added content of trade, we build on an active literature on the construction of global input-output tables, including Johnson and Noguera (2012b). The basic approach is to link national input-output tables together using bilateral trade data to form a synthetic global input-output table that tracks shipments of both final and intermediate goods between countries. The resulting framework can be used to construct the value added content of bilateral trade, tracking value added from the location at which it is produced to the destination at which it is absorbed in final demand.

At an intuitive level, if one knows the entire global input-output structure, then one can compute how much output from each source country is needed (either directly or indirectly) to produce final goods absorbed in each destination. If one also knows the value added to output ratios

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used in producing that output in the source, then one can compute the value added embodied in that implicit gross output transfer. We call the value added produced in country i and absorbed in country j “value added exports” and denote the bilateral flow by VA_{ij} . In our work below, we focus on comparing these value added exports to gross exports, which we notate X_{ij} . We devote special attention to the ratio of value added to gross trade, which we term the “VAX ratio.”

Previous researchers have constructed these global input-output tables for short time horizons, often a single year or at most a decade. In Johnson and Noguera (2012a), we extend this work by bringing together data on trade, production, and input use at the sector level for 1970–2009.¹ This data allows us to construct a sequence of global input-output tables, one for each year, and therefore track changes in intermediate sourcing, final goods flows, and hence the value added content of trade over time.

Importantly, the time series dimension includes information that helps identify the causes and consequences of fragmentation. Changes in fragmentation differ across countries both in absolute magnitudes and in the timing of those changes, which opens the door to linking these changes to observables. Further, in a regression context, this type of data allows one to link changes in fragmentation to changes in bilateral trade costs, controlling for time-varying source and destination characteristics as well as pair-specific characteristics that are fixed over time.

We combine data from several sources, including the Organisation for Economic Cooperation and Development (OECD) Input-Output Database, the United Nations (UN) National Statistics Database, the National Bureau of Economic Research-UN Trade Database, and the Centre d’Etudes Prospectives et d’Informations Internationales (CEPII) Base pour l’Analyse du Commerce International (BACI) Database.² In calculations below, we aggregate this data to form four composite sectors: agriculture and natural resources, nonmanufacturing industrial

production, manufacturing, and services. Based on data availability, we include 42 countries in the framework, covering the OECD plus major emerging markets (including Brazil, China, India, Mexico, and Russia). We aggregate the remaining countries to form a rest-of-the-world region.³

II. Fragmentation inside versus outside Regions

We begin by defining proximity in terms of regions, grouping countries into regions R . To quantify fragmentation inside versus outside each region, we compute the VAX ratio for trade between countries inside the region ($i, j \in R$) and compare it to the VAX ratio for trade between countries in the region and partners outside the region ($k \notin R$). We define the VAX ratio for trade inside the region as $VAX_{IN} \equiv \frac{VA_{IN}}{X_{IN}}$, where $VA_{IN} \equiv \sum_{i \in R} \sum_{j \in R} VA_{ij}$ and $X_{IN} \equiv \sum_{i \in R} \sum_{j \in R} X_{ij}$.⁴ Similarly, define the VAX ratio for trade outside the region as $VAX_{OUT} \equiv \frac{VA_{OUT}}{X_{OUT}}$, where $VA_{OUT} \equiv \sum_{i \in R} \sum_{k \notin R} (VA_{ik} + VA_{ki})$ and $X_{OUT} \equiv \sum_{i \in R} \sum_{k \notin R} (X_{ik} + X_{ki})$.

We compute these VAX ratios for three regions (North America, East Asia, and Europe) and report results for four years (1975, 1985, 1995, and 2005) in Table 1. There are three points to take away from the table.

First, VAX ratios are falling over time both inside and outside regions. Thus, fragmentation is increasing on both the local and global scale. The size of the decline varies across regions and trading partners, but is in the range of 0.10 to 0.15.

Second, VAX ratios are lower for trade inside regions than trade outside them in each year. For example, the VAX ratio is around 0.20 smaller inside Europe than outside Europe, depending on the year. This holds true for the other regions as well, and suggests that intraregional trade is more fragmentation-intensive than trade outside regions.

¹ Hummels, Ishii, and Yi (2001) constructed measures of fragmentation for ten countries over 1970–1990. Our work both extends country and time coverage and, most importantly, adds a bilateral dimension to the measurement of fragmentation over time. a

² See Johnson and Noguera (2012a) for details.

³ We assume that exports from the 42 countries to the rest of the world are absorbed there. The Czech Republic, Estonia, Russia, Slovakia, and Slovenia are included in the rest of the world during the first two decades and separately thereafter.

⁴ Note that $X_{ii} = 0$ by definition of exports, and we set $VA_{ii} = 0$ here for notational convenience.

TABLE 1—VALUE ADDED-TO-EXPORT RATIOS INSIDE VERSUS OUTSIDE GEOGRAPHIC REGIONS

	Europe			East Asia			North America		
	VAX_{IN}	VAX_{OUT}	Δ in/out	VAX_{IN}	VAX_{OUT}	Δ in/out	VAX_{IN}	VAX_{OUT}	Δ in/out
1975	0.70	0.87	-0.17	0.77	0.88	-0.11	0.81	0.94	-0.13
1985	0.65	0.85	-0.20	0.73	0.87	-0.14	0.78	0.92	-0.14
1995	0.65	0.84	-0.19	0.75	0.88	-0.13	0.66	0.89	-0.23
2005	0.59	0.79	-0.20	0.61	0.79	-0.19	0.64	0.85	-0.21
Δ time	-0.11	-0.08		-0.16	-0.08		-0.16	-0.08	

Notes: Europe includes EU members who joined prior to 2004. East Asia includes China, Indonesia, Japan, South Korea, Thailand, and Vietnam. North America includes Canada, Mexico, and the United States.

Third, the gap between VAX_{IN} and VAX_{OUT} is growing over time. This can be seen in total changes from 1975 to 2005, which are larger for trade inside regions relative to outside regions. Further, looking decade by decade, changes are not uniform through time. For example, the large gap between inside and outside VAX ratios for North America emerges during the 1985–1995 decade, the period in which the Canada-United States Free Trade Agreement (CUSFTA) and the North American Free Trade Agreement (NAFTA) were introduced. The fact that VAX ratios are falling most rapidly within regions implies that fragmentation is concentrated among geographically proximate countries.

III. Distance and Fragmentation

To explore the link between proximity and fragmentation further, we turn to distance as a measure of proximity. To measure distance, we use the population-weighted distance (in kilometers) between two countries from the CEPII Distances database.⁵ We perform two exercises. First, we compute the average distance between source and destination for gross and value added trade, and compare these distances through time. Second, we assess how changes in bilateral VAX ratios from 1970 to 2009 are related to distance.

We draw on work by Carrère and Schiff (2005) to measure the average distance between source and destination for the two types of trade. For each country, we define distance traveled as a weighted average of bilateral distances d_{ij} , where the weights are either gross or value added trade shares. To be explicit, export distances for country i are

$$DoT_i^x \equiv \sum_{j \neq i} \left(\frac{X_{ij}}{X_i} \right) d_{ij}$$

$$DoVAT_i^x \equiv \sum_{j \neq i} \left(\frac{VA_{ij}}{VA_i} \right) d_{ij},$$

where the x superscript denotes exports, $X_i \equiv \sum_{j \neq i} X_{ij}$ is total gross exports, and $VA_i \equiv \sum_{j \neq i} VA_{ij}$ is total value added exports.

Distances for imports (DoT_i^m and $DoVAT_i^m$) can be measured analogously. Then, we compute distances for the world by weighting each country by their share of global exports or imports.

In the figures, we focus on the difference between distance for gross trade and value added trade.⁶ We plot distances for all countries, and distances for the United States and Japan separately, in Figure 1.⁷

In both the aggregate and for individual countries, the average distance for gross trade is smaller than for value added trade. To benchmark this value, the distance traveled by gross trade is roughly 10 percent smaller than the distance traveled by value added trade.⁸ Further, the distance traveled by gross trade is falling relative to distance traveled by value added trade,

⁶ As Carrère and Schiff (2005) point out, distances for gross trade are falling in many countries, and we find the same to be true of value added trade. By looking at the difference, we focus on the relative size of these downward trends.

⁷ The figures are computed using bilateral trade among the 37 countries for which we have a complete 1970–2009 time series (see footnote 3). Distances for the United States and Japan are averaged over exports and imports using trade weights.

⁸ Across all years, the median distance traveled by gross trade is about 4,400 km, while the median distance traveled by value added trade is 4,900 km.

⁵ See <http://www.cepii.fr>.

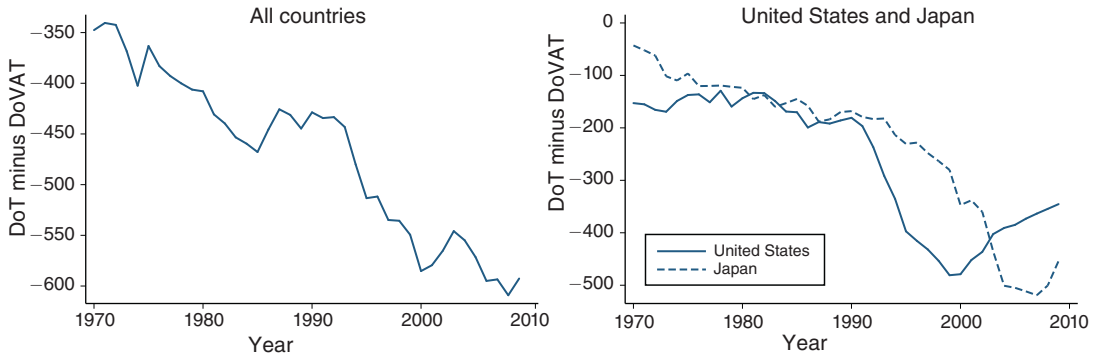


FIGURE 1. DIFFERENCE IN DISTANCE TRAVELED FOR GROSS AND VALUE-ADDED TRADE

pointing to fragmentation increasing among nearby partners. Gross trade travels 7 percent shorter distance than value added in 1970, versus 12 percent in 2009.

The timing of these changes in individual countries is suggestive regarding mechanisms. Echoing the regional results above, we see US distances falling sharply in the 1990–2000 period during which CUSFTA and NAFTA take force. For Japan, we see sharp declines only after 1995, which hints at the reorientation of Asian supply chains in which Japan increasingly ships intermediates to processing and assembly destinations within Asia (e.g., China).

These average distance measures are suggestive evidence of the localization of gross trade relative to trade in value added over time. To look directly at gross and value added flows, we turn to regressions. Specifically, we compute the change in log bilateral gross exports, log bilateral value added exports, and the log of the bilateral VAX ratio between 1970 and 2009. We then regress these changes on exporter and importer fixed effects and the log of bilateral distance ($\log(d_{ij})$).⁹ The exporter and importer fixed effects allow individual source and destination countries to experience different changes on average, while the coefficient on distance measures whether changes are larger or smaller for countries that are farther apart.

Table 2 reports the regression results.¹⁰ In the first column, we see that the decline in the VAX ratio for a given bilateral pair is smaller as distance between the pair increases. Plainly, VAX ratios fall more for nearby country pairs than for faraway country pairs. The second and third columns report results for log exports and log value added exports as well. Because $\log(VAX_{ij}) = \log(VA_{ij}) - \log(X_{ij})$ by construction, the difference in coefficients on distance in these regressions equals the coefficient on the VAX ratio in the first column. Yet in these columns we can look at how changes in gross and value added trade together generate the overall change in the VAX ratio. Changes in both value added and gross trade are related negatively to distance, which implies that both value added and gross trade have become more localized over time in absolute terms. Interestingly, this phenomenon is stronger for gross trade than for value added trade, and this is what makes changes in the VAX ratio correlated with distance.

Both ways of looking at the role of distance in shaping gross and value added trade yield the same end result. Changes in fragmentation are associated with differential growth in gross relative to value added trade at short distances. As such, the rise of fragmentation appears to be related intimately to growing localization of international trade.

⁹ In these regressions, we drop observations for which bilateral trade is less than \$1 million in 1970 to remove outlier VAX ratios.

¹⁰ Regarding model fit, the fixed effects account for most of the overall variation, since country-specific changes in trade and VAX ratios are large. For the VAX ratio, distance accounts for 17 percent of the overall R^2 .

TABLE 2—DISTANCE AND CHANGES IN BILATERAL TRADE

	$\Delta(\log(VAX_{ij}))$	$\Delta(\log(X_{ij}))$	$\Delta(\log(VA_{ij}))$
$\log(d_{ij})$	0.10*** (0.01)	-0.22*** (0.04)	-0.12*** (0.03)
R^2	0.53	0.65	0.70
Within R^2	0.09	0.04	0.02
Observations	1,090	1,090	1,090

Notes: The dependent variable is defined: $\Delta(\log(Z_{ij})) \equiv \log(Z_{ij}^{2009}) - \log(Z_{ij}^{1970})$ for $Z \in \{VAX_{ij}, X_{ij}, VA_{ij}\}$. Exporter and importer fixed effects included in all regressions. Robust standard errors are in parentheses.

***Significant at the 1 percent level.

IV. Conclusions

Collectively, these results point to a strong role for proximity in explaining fragmentation patterns, and hence changes in trade patterns over time. There are of course many mechanisms through which distance may matter. Most directly, distance may be important due to costs of transporting goods across space. At the same time, distance may simply be a proxy for other observables, such as language dissimilarity, that impede trade. Another concern is that distance or geographic regional membership may be picking up the effect of regional integration initiatives, such as deepening of the European Union

or NAFTA over time. More work is needed to sort out these possible channels.

Further, work aimed at quantifying how important trade frictions are relative to country-specific determinants of fragmentation would be valuable, likely using models of fragmentation in which trade costs take center stage, as in Yi (2010). We expect that the identifying information contained in the time-varying bilateral value added trade flows introduced in this note will be helpful in these endeavors.

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