

The evolution of world trade from 1995 to 2014: A network approach

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TAKE HOME MESSAGES...

- Focus on the main connective features of the world trade network (WTN) and their dynamics (1995-2014).
- Countries' efforts to attain the benefits of trade have resulted in an intertwined network that is increasingly dense, reciprocal, and clustered.
- Trade linkages are distributed homogeneously among countries, but their intensity (i.e. their value) is highly concentrated in a small set of countries.
- The main connective features of the WTN were not affected by the 2007-2008 international financial crisis.
- The crisis marks a turning point in the evolution of the WTN from a twogroup (led by the US and Germany) to a three-group (led by the US, Germany, and China) hierarchical structure... Gravity model's hypothesis?
- WTN's connective features do not conform to a linear aggregation of sectorial trade networks.



- Introduction
- Literature review
- Methodology and data
 - Network analysis
 - Data
- Main results
 - The world trade network (WTN)
 - WTN's hierarchical structure
 - The WTN by sector
- Final remarks



INTRODUCTION

- International trade of goods and services grew about 380 per cent from 1994 to 2014, from about US\$5 trillion to US\$24 trillion, whereas the share of trade of goods and services in global GDP rose from about 20 per cent in the eighties to over 30 per cent in 2013 (UNCTAD, 2015).
- Exports from advanced economies and developing countries are nowadays more diversified (WTO, 2013).
- Trade has been identified as one of the engines of economic growth (Dollar, 1992, Krueger, 1998, Edwards, 1998, Stiglitz, 1998, Frankel & Romer, 1999, Arora & Vamvakidis, 2005).
- Studying the main features of world trade in the last decades has become of particular interest for policymakers as it is related to economic growth, contagion channels and capital flows.



INTRODUCTION

- **Objective**: To characterize and examine world trade as a network, in what is commonly known as the world trade network (WTN).
- This approach allows for a better description of international economic integration by considering the various dimensions of connectivity that arise when countries trade among them (Fagiolo et al., 2010).
- Questions we address:
 - What are the main network features of WTN?
 - How has the WTN evolved in the last two decades?
 - Were the WTN's main features affected by the 2007-08 crisis?*
 - What does WTN's hierarchical structure reveal?
 - Has this hierarchical structure changed during the last two decades?
- We do not study individual cases (e.g. countries, regions) or answer Why? type of questions.



(*) "[...] world trade declined rapidly beginning in the third quarter of 2008 through the second quarter of 2009. [...] the decline was the largest in the last forty years" (Shelburne, 2010, p.1).



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- Main results
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LITERATURE REVIEW*



*There is no unique dataset (e.g. Comtrade-UNCTAD, IMF, BACI-CEPII), nor a unique data processing procedure in literature.



Source: Authors' review and design.

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 - Data
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NETWORK ANALYSIS

- Aim: Describing and understanding an underlying system, focused on capturing the system's structure (Börner et al., 2007).
- Process: network sampling, measurement, and visualization.
- Network analysis basics:
 - Network: representation of a system –a set of elements related by their links.
 - In our case, countries as nodes or vertexes; exports as links or edges.
 - The most common numerical representation is the adjacency matrix (non-weighted or weighted) –an edge list is also common.
 - The most common visual representation is a graph.

 $A_{ij} = \begin{cases} 1 \text{ if there is an edge from } i \text{ to } j, \\ 0 \text{ otherwise.} \end{cases}$





NETWORK ANALYSIS

- Basic measures and metrics (Börner et al., 2007, Newman, 2010):
 - <u>Degree</u>: number of edges connected to a node (in-, out-, average-).
 - <u>Strength</u>: weight of edges connected to a node (in-, out-, average-).
 - <u>Density</u>: cohesion of the network; ratio of number of actual edges to maximum possible number of edges $[0 < d \leq 1]$.
 - <u>Mean geodesic distance</u>: mean of all shortest paths between reachable nodes.
 - <u>Reciprocity</u>: probability that an edge from *i* to *j* is complemented by the reciprocal edge, from *j* to *i* (i.e. a dyadic).
 - <u>Clustering coeff.</u>: probability that two neighbors of a node are neighbors themselves (i.e. a triadic).
 - <u>Assortativity coeff. by degree (strength)</u>: measures the extent to which similar nodes by degree (strength) tend to connect —akin to a correlation by degree (strength).



NETWORK ANALYSIS

- Basic measures and metrics (Börner et al., 2007, Newman, 2010):
 - <u>Degree (strength) power-law exponent:</u>
 - Measures the skewness of degree (strength) distribution -to determine if it is inhomogeneous, presumably a scale-free network.
 - If in the range $2 \le \gamma_{k} \le 3$ for degree are typical of scale-free networks (Barabási & Albert, 1999).



- Introduction
- Literature review
- Methodology and data
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 - Data
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DATA

- <u>Source</u>: Exports (FOB) from UN-Comtrade Dataset (<u>http://comtrade.un.org/</u>)
- <u>Period</u>: 1995 to 2014 (20 periods)
- <u>Frequency: Annual</u>
- <u>Classification</u>: a multi-layer network of world trade by traded goods (16 classes) –a multiplex network (Kivelä et al., 2014; D'Agostino & Scala, 2014).
- <u>Setup</u>: maximizing the number of countries while avoiding biases due to non-reporting countries.
 - Ten biennial periods: avoid non-consecutive or non-reporting by interesting players (e.g. Czech Republic, Ecuador, Russia, ... Venezuela).
 - Ten equally-sized networks: discarding countries that do not report in all biennial periods (106 countries out of 163, about 93,13% of total world trade).
 - We do not filter trade relations by their value or the size of the country; we attempt to preserve and acknowledge the importance of all trade linkages.



DATA

		Table 1					
	Classification	s and Commodity Codes					
Network	Codes HS	Sactors					
	2 digit	Sectors					
1	01-05	Animal & animal products					
2	06-15	Vegetable products					
3	16-24	Foodstuffs					
4	25-27	Mineral products					
5	28-38	Chemicals & allied industries					
6	39-40	Plastics & rubbers					
7	41-43	Raw hides, skins, leather, & furs					
8	44-49	Wood & wood products					
9	50-63	Textiles					
10	64-67	Footwear & headgear					
11	68-71	Stone & glass					
12	72-83	Metals					
13	84-85	Machinery & electrical					
14	86-89	Transportation					
15	90-97	Miscellaneous					
16	98-99	"Other" (Service)					
17	01-99	World trade network					

This classification is based on the Harmonized System (HS) two-digit product disaggregation. Based on Comtrade.





Figure 2. A sample five-country two-sector trade hypothetical multiplex network. Two single-layer networks, A and B, and the multiplex resulting from merging A and B. Vertical lines connecting superimposed vertexes are the countries, whereas each vertex is a role in the corresponding layer. Source: Authors' design.

- Introduction
- Literature review
- Methodology and data
 - Network analysis
 - Data
- Main results
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WTN: NETWORK VISUALIZATION









0.04

0.035

0.03

0.025

0.02

0.015

0.01

0.005















0.025

0.02

0.015

0.01

0.005





















Source: Authors' calculations and design.



Key common features

- 1. Network is densely connected.
- 2. Edges are homogeneously distributed.
 - 3. Few countries contribute with intense edges.
- 4. Few countries are dominant by diameter.

Key changes

- 1. A drastic change in the ranking of countries as contributors to the total value of exports:
 - BRA from 23rd to 19th
 - RUS from 19^{th} to 14^{th}
 - IND from 29th to 18th At the expense of JPN, CHN from 11th to 2nd DEU, ITA, GBR, CAN...
 - CHN from 11^{th} to 2^{nd}
 - HKG from 9th to 5th
 - MEX from 16^{th} to 13^{th}
- 2. Most intense edges are now less concentrated (see the color scale, and the number of intense relations).

Table 2

Topological metrics for the world trade network										
Period	d	l	r	С	a_k	a_s	Υĸ	γ_s		
1995-1996	0.74	1.26	0.88	0.53	0.57	0.07	25.23	2.82		
1997-1998	0.76	1.24	0.88	0.56	0.58	0.07	21.91	1.77		
1999-2000	0.78	1.22	0.89	0.57	0.58	0.07	42.04	1.77		
2001-2002	0.80	1.20	0.90	0.61	0.58	0.08	64.70	1.85		
2003-2004	0.82	1.18	0.90	0.62	0.58	0.08	35.97	1.88		
2005-2006	0.83	1.17	0.91	0.66	0.58	0.08	22.77	1.95		
2007-2008	0.85	1.15	0.92	0.68	0.59	0.08	47.65	1.99		
2009-2010	0.85	1.14	0.91	0.66	0.59	0.08	15.49	2.06		
2011-2012	0.86	1.13	0.92	0.68	0.59	0.08	31.65	2.09		
2013-2014	0.85	1.14	0.91	0.66	0.58	0.08	19.77	2.55		
Average	0.81	1.18	0.90	0.62	0.58	0.08	32.72	2.07		

The metrics displayed are density (d), mean geodesic distance (l), reciprocity (r), clustering coefficient (c), assortativity coefficient by degree (a_k) , assortativity coefficient by strength (a_s) , power-law exponent by degree (γ_k) , power-law exponent by strength (γ_s) . Source: Authors' calculations.

Key features

- 1. Densely connected.
- 2. Increasingly dense.
- 3. Reduced distances.
- 4. Highly reciprocal.
- 5. Highly clustered.
- 6. High and positive assortativity by degree*.
- 7. Low but positive assortativity by strength*.
- 8. Degree displays no inhomogeneous distribution features.
- 9. Strength displays inhomogeneous features.





Figure 4. Contour plot of the distribution of degree (panel a.) and strength (panel b.). The distribution of degree is not right-skewed but left-skewed; most countries share a similar high number of trade partners. The distribution of strength among countries is right-skewed; most countries contribute marginally to total value of exports, whereas a few contribute greatly. Source: Authors' calculations.



- Evidence points out that WTN does not fit the inhomogeneous (e.g. scale-free) features typical of real-world networks...
- ... nor a core-periphery network model (*sparsely connected periphery*).
- Our results concur with homogeneity findings by Kali and Reyes (2007), Fagiolo et al. (2010), and Barigozzi et al. (2010); but contradict scale-free characterizations by Serrano and Boguñá (2003) and De Benedictis et al. (2013).
- It is fair to say that high connectedness (density) drives this result, with most countries sharing similar high numbers of trade partners.



Some straightforward insights ...

- Scale-free and inhomogeneous networks have been related to preferential attachment dynamics (see Barabási & Albert, 1999).
- Core-periphery network models have been related to decreasing returns to connectedness (see Hojman & Szeidl, 2008 and Fricke & Lux, 2015a).
- Therefore, finding a dense and homogeneous distribution of links suggests that...
 - Countries do not show a clear preference to establish relations with a small set of well-connected countries, but a preference to maximize their trade partners.
 - Establishing trade relations with an additional country does not necessarily require weakening or neglecting prior trade relations*, thus maximizing the number of trading partners may be an optimal strategy.



(*) Increasing the number of linkages is costly in other social or financial networks. In the latter, establishing linkages increases risk exposure or monitoring costs, or the depletion of finite resources (e.g. interbank lending networks).

Some straightforward insights ... (2)

• From a network optimization viewpoint (Ferrer i Cancho & Solé, 2003 and Hojman & Szeidl, 2008), our results suggest that the structure of the WTN is driven by the benefits of establishing trading relations for countries (e.g. fostering and diversifying exports, spurring economic growth), with those benefits not exhibiting a strong marginal decrease as the number of trade partners increase amid falling trade costs and frictions.



- Introduction
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- Main results
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WTN'S HIERARCHICAL STRUCTURE

- Visualizing the WTN as a graph is interesting...
- Yet, it is particularly difficult to identify the most important trading partner of a country, or the overall network structure (Maeng et al., 2012, Ospina, 2013).
- Therefore, we implement a dimensionality reduction technique (*minimal spanning tree MST*) to filter the graph.
- MST chooses the minimal weights (i.e. shortest distances) of a connected system in such a way that all (n) nodes are preserved but with a subset of n 1 links that minimize the system's weight (León et al., 2014).
- MST is the "skeleton" or "backbone" inside the network (Wu et al., 2006).



WTN'S HIERARCHICAL STRUCTURE





Source: Authors' calculations and design.



FIN

- EST

• FRA

* MAR DZATUN

• ESP *

PRT

1997-1998



PAN JPN

SGPCHNBRA

• HKG

• ARG

MYS

. IDN

AUSTHA

* NZL



This visualization includes all countries that pertain to the 99th percentile by contribution to total exports –for visual clarity.





Key common features

- 1. Clusters are easily identified.
- 2. Geographical + cultural clustering is evident.
- 3. There are dominant countries that lead the hierarchy, and they are those that contribute the most to exports by value.

<u>Key changes</u>

- From a two-large-clusters hierarchy, to a three-large-clusters hierarchy: from USA – DEU to DEU – USA – CHN.
- 2. This change overlapped with the 2007-08 crisis -coincidence?
- 3. Less geographical clustering:
 - 1. CHN summons distant countries (ARG, BRA, NGA, CHL) and entire regions (RUS & UKR).
 - 2. USA cluster decreases from 22 to 11 countries; keeps some continental partners and SAU & ISR.
 - 3. DEU cluster decreases in size, from 34 to 28 countries.



Plausible explanations for the key changes?

Consistent with gravity models of international trade...

- 1. CHN has surpassed DEU as the second largest economy since 2005*
- 2. The size gap between CHN and USA has narrowed*
- 3. The distance effect has decreased as trade costs have diminished in the last decades

... Thus, CHN should be an increasingly strong gravitational force for the WTN.

Consistent with empirical evidence regarding the strong influence of trading partners' growth on a country's economic growth (Arora & Vamvakidis, 2005), it is fair to say that fastgrowing countries (as CHN) should be more likely to attract trade flows as well.

(*) Measured as GDP (constant 2010 values, in US dollars)

- Introduction
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- Methodology and data
 - Network analysis
 - Data
- Main results
 - The world trade network (WTN)
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- Final remarks



WTN BY SECTOR

Table 3 Average topological metrics for the world trade network by sectors ^a											
World trade network ^b	0.81	1.18	0.90	0.62	0.58	0.08	32.72	2.07			
Machinery & electrical	0.65	1.34	0.82	0.40	0.53	0.05	22.59	2.50			
Miscellaneous	0.62	1.37	0.82	0.39	0.54	0.05	11.82	1.98			
Textiles	0.62	1.38	0.82	0.40	0.56	0.06	12.44	1.98			
Wood & wood products	0.60	1.39	0.82	0.39	0.55	0.05	17.31	2.29			
Chemicals & allied industries	0.60	1.40	0.78	0.34	0.52	0.04	14.80	1.73			
Metals	0.59	1.41	0.80	0.35	0.53	0.05	9.60	2.31			
Foodstuffs	0.58	1.42	0.80	0.37	0.56	0.06	14.38	2.02			
Plastics & rubbers	0.57	1.43	0.77	0.32	0.51	0.04	20.61	2.20			
Vegetable products	0.55	1.45	0.79	0.39	0.61	0.06	7.82	1.94			
Transportation	0.53	1.46	0.76	0.30	0.52	0.04	7.08	1.80			
Stone & glass	0.53	1.47	0.78	0.33	0.54	0.04	13.10	1.66			
Animal & animal products	0.48	1.52	0.74	0.31	0.58	0.05	8.56	1.81			
Mineral products	0.47	1.54	0.76	0.31	0.58	0.05	11.57	3.61			
Raw hides, skins, leather & furs	0.45	1.55	0.77	0.31	0.58	0.05	15.41	1.89			
Footwear & headgear	0.43	1.57	0.71	0.26	0.55	0.04	10.51	1.77			
"Other"	0.27	1.51	0.60	0.16	0.54	0.03	20.08	2.11			

^a The metrics displayed are density (*d*), mean geodesic distance (*l*), reciprocity (*r*), clustering coefficient (*c* assortativity coefficient by degree ($a_{\hat{k}}$), assortativity coefficient by strength (a_{s}), power-law exponent by degre ($\gamma_{\hat{k}}$), power-law exponent by strength (γ_{s}). ^b Corresponds to the biennial average of world trade network, a reported in Table 2. Source: Authors' calculations.



Key features of all sectors

- 1. Densely connected, but less than the WTN
- 2. Reduced distances, but higher than the WTN
- 3. Highly reciprocal, but less than the WTN
- 4. Highly clustered, but less than the WTN
- 5. High and positive assortativity by degree
- 6. Low but positive assortativity by strength
- 7. Degree displays no inhomogeneous distribution features; some sectors get closer, but still do not
- 8. Strength displays inhomogeneous features in all cases

WTN BY SECTOR

- Sectors display same overall features when compared to WTN
 - Dense
 - Low distance
 - Reciprocal
 - Clustered
 - Assortative by degree* / strength*
 - Homogeneous by the distribution of degree
 - Inhomogeneous by the distribution of strength
- Thus, WTN and its sectors do not conform to what is expected from most real-world networks
- Besides, it is evident that the sum of sectors do not yield the WTN. Aggregating or averaging statistics by sectors do not deliver the statistics displayed by the WTN.



- Introduction
- Literature review
- Methodology and data
 - Network analysis
 - Data
- Main results
 - The world trade network (WTN)
 - WTN's hierarchical structure
 - The WTN by sector
- Final remarks



FINAL REMARKS...

- Countries' efforts to attain the benefits of trade have resulted in an intertwined network that is increasingly dense, reciprocal, and clustered.
- Trade linkages are distributed homogeneously among countries, but their intensity (i.e. their value) is highly concentrated in a small set of countries.
- The main connective features of the WTN were not affected by the 2007-2008 international financial crisis.
- The crisis marks a turning point in the evolution of the WTN from a two-group (led by the US and Germany) to a three-group (led by the US, Germany, and China) hierarchical structure.
- WTN's connective features do not conform to a linear aggregation of sectorial trade networks.



FINAL REMARKS...

- Policy implications
 - New insights for analyzing and understanding world and regional trade
 - The outcome of liberalization is an increasingly dense and homogeneous WTN
 - WTN's network features were rather robust to the 2007-08 crisis
- Pending issues
 - Examining how particular regions or countries have integrated to the WTN by means of measuring their network centrality
 - Aggregating hundreds (or thousands) of products in a single sector may obscure interesting features of more granular networks
 - Examining the exchange of services (e.g. financial, insurance, transport, education, remittances)
 - Examining capital flows
 - Revising our assortative/disassortative measurement methods



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