Tilburg University

The Evolution of World Trade from 1995 to 2014

Cepeda, Fredy; Gamboa, Freddy; Leon Rincon, Carlos; Rincon, Hernan

Publication date:
2017

Document Version
Early version, also known as pre-print

Citation for published version (APA):
Cepeda, F., Gamboa, F., Leon Rincon, C., & Rincon, H. (2017). *The Evolution of World Trade from 1995 to 2014: A Network Approach*. (CentER Discussion Paper; Vol. 2017-008). CentER, Center for Economic Research.

No. 2017-008

THE EVOLUTION OF WORLD TRADE FROM 1995 TO 2014: A NETWORK APPROACH

By

Freddy Cepeda, Fredy Gamboa, Carlos León, Hernán Rincón

22 February 2017

ISSN 0924-7815
ISSN 2213-9532

The evolution of world trade from 1995 to 2014: A network approach[1]

Freddy Cepeda[2]
Fredy Gamboa[3]
Carlos León[4]
Hernán Rincón[5]

Abstract

This paper employs network analysis to study world trade from 1995 to 2014. We focus on the main connective features of the world trade network (WTN) and their dynamics. Results suggest that 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. However, we find that 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; gravity models of international trade may explain this evolution. Furthermore, we find that WTN's connective features do not conform to a linear aggregation of sectorial trade networks.

JEL Classification: F10, F14, D85

Key words: world trade, network analysis, graph, minimal spanning tree

---

[1] The opinions and statements in this article are the sole responsibility of the authors, and do not represent neither those of Banco de la República nor of its Board of Directors. We thank Andrés Pinchao and Jesahel Higuera for their excellent research assistance. Any remaining errors are our own.

[2] Financial Infrastructure Oversight Department, Banco de la República, Bogotá, Colombia. fcepedlo@banrep.gov.co.

[3] Monetary and International Investment Division, Banco de la República, Bogotá, Colombia. fgamboes@banrep.gov.co.

[4] Financial Infrastructure Oversight Department, Banco de la República, Bogotá, Colombia; CentER, Tilburg University. cleonrin@banrep.gov.co / carlosleonr@hotmail.com. Correspondent author at Carrera 7 #14-78, Bogotá, Colombia; Tel.+57 1 3430731.

[5] Research Unit, Banco de la República, Bogotá, Colombia. hrincoca@banrep.gov.co.

1 Introduction

World trade has increased dramatically during the last four decades, facilitated –among other factors- by the reduction of policy barriers, transportation, and communication costs (Frankel, 2000, WTO, 2013). For instance, as reported by UNCTAD (2015), the 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. Even though advanced economies are still the main players in international trade, developing economies account for over 45 per cent of world trade. As documented by UNCTAD (2015), trade between developing countries have stopped growing since 2011, while trade between developing and advanced economies has increased considerably, representing about 40 per cent of world trade in 2013. In addition, 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). Developing economies, especially in Asia, have experienced higher average GDP growth rates than developed countries during the last decades, which have been attributed to a notable increase in exports and imports (WTO, 2013). On the other hand, UNCTAD reports that some Latin American and African countries have seen a recent decline in international trade due to their dependency on price-declining commodities; this, in turn, has weakened growth in commodities-exporting countries (see Gruss, 2014).

Therefore, studying the main features of world trade in the last decades has become of particular interest for policymakers. Further understanding trade linkages among countries serves the purpose of strengthening our knowledge about economic growth, the consequences of trade liberalization, and the existence of contagion channels. Moreover, as trade flows are related to capital flows, understanding the different connections among trade partners will bring to light their macroeconomic and financial links.

The objective of this paper is to characterize and examine world trade as a network, in what is commonly known as the world trade network (henceforth WTN) –also referred as international trade network or world trade web. This approach regards world trade as a complex system, in which there is myriad of elements (i.e. countries), whose numerous interactions (i.e. exports and imports) make them interdependent at the individual and aggregate level. The value of the network approach for examining and analyzing the WTN results from its ability to cope with its complexity (Serrano & Boguñá, 2003). In our case, unlike traditional openness metrics (e.g. trade to GDP ratios), network analysis captures how countries connect to each other by means of exports and imports, hence it allows for a better description of international economic integration by considering the various dimensions of connectivity that arise when countries trade among them (see Fagiolo et al., 2010). Furthermore, as highlighted by Serrano and Boguñá (2003), the characterization of the WTN is of primary interest for crisis propagation modeling, as well as for understanding of liberalization on the world trade system.

Several questions are to be addressed in this paper: How has the WTN evolved in the last two decades? Which are the main features of this network? Does the WTN share common features with sectorial (by product) trade networks? As world trade collapsed during the crisis[6], were the main features of the WTN affected by the 2007-2008 international financial crisis? What may be the rationale behind WTN's structure and dynamics? What does WTN's hierarchical structure reveal? Has this hierarchical structure changed during the last two decades?

To tackle these questions, this paper applies network analysis (Börner et al., 2007) on the WTN, which aims at describing and understanding the system of international trade. Our approach not only allows us to identify and characterize the connective structure of the network in the 1995-2014 period, but also the position or integration of each economy to the world trade. However, in this paper we focus on the connective and hierarchical features of the WTN, and we reserve the study of how individual economies or regions integrate to the global trade network for an ongoing research.

Regarding our main findings, there are several worth noting. Firstly, given the lack of consensus about some of WTN's main connective features, we provide new results that support evidence of a dense and homogeneous distribution of connections. Secondly, our results overlap with those by Fagiolo et al. (2010), who report that the structural properties of WTN are rather stationary, with the increase in density and reciprocity suggesting that globalization has resulted in an increased number of trade relations with no sizable effect on their intensity. Thirdly, our results suggest that the 2008-2009 crisis did not affect the main connective properties of the WTN; however, an interruption in the increasing path of connectedness and other related metrics is visible. Fourthly, results suggest that the 2008-2009 crisis marks a turning point in WTN's evolution from a two-group (led by the US and Germany) to a three-group (led by the US, Germany, and China) hierarchical structure of world trade; we suggest that this evolution may be explained by gravity models of international trade (see Isard & Peck, 1954, Tinbergen, 1962, Anderson, 1979, Bergstrand, 1989, Anderson & Wincoop,

---

[6] As reported by Shelburne (2010, p.1), "[…] 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".

2003). Finally, concurrent with Barigozzi et al. (2010), we find that WTN's connective features do not conform to a linear aggregation of sectorial (by product) trade networks.

This document consists of four sections aside from the introduction. The second section presents a review of related literature and identifies how our approach augments and updates it. The third section describes the methodology and data. The fourth presents and analyzes the results. The last section summarizes the main findings, discusses policy implications, and envisages additional research paths that may follow.

2 Literature review

Network analysis has been used to study world trade. Nevertheless, the literature is not that abundant. The most influential research we are aware of are Serrano and Boguñá (2003), Kali and Reyes (2007), Fagiolo et al. (2010), Barigozzi et al. (2010), De Benedictis and Tajoli (2011), Maeng et al. (2012), and De Benedictis et al. (2013).

Serrano and Boguñá (2003) present an empirical characterization of the WTN –which they claim is the first of its kind. They use a partial dataset extracted from United Nations' Comtrade Database (hereafter Comtrade), comprising the forty more important exchanged merchandises for 179 countries in year 2000. The dataset is filtered in order to preserve trade connections that are relevant, at least, to one of the two involved countries. They conclude that the network displays the typical features observed in other complex networks (e.g. the Internet), such as a particularly right-skewed (i.e. extremely heterogeneous) distribution of links, presumably in the form of a scale-free network[7]; a reduced average distance between countries; and a clustered structure. They report that the trade network is rather reciprocal, with a high fraction of bidirectional connections, in which there is a positive correlation between the number of connections of a country and its *per capita* GDP. However, as acknowledged by them, bounding the network to the forty more important merchandises per country may limit their analysis –along with the filtering process to work with relevant trade connections only.

Kali and Reyes (2007) use Comtrade data to analyze the WTN at two points in time, 1992 and 1998, which comprise 189 and 192 countries, respectively. They discriminate between a restricted

---

[7] As explained in a forthcoming section, the scale-free characterization corresponds to networks that display an extremely right-skewed distribution of connections, in the form of a power-law decay. In this type of network there are a few heavily connected participants and many poorly connected participants, in which there is no typical or representative participant; thus, the distribution of connections has no scale, it is scale-free or scale-invariant (León & Berndsen, 2014).

and unrestricted trade network, with the former filtering out low-value trade links. For the unrestricted WTN they find that it is dense (i.e. highly connected), decentralized, and homogeneous, and has become much more integrated over time. For the restricted case (i.e. high traded values only) they find that the WTN displays a core-periphery structure[8], and is particularly heterogeneous, presumably in the form of a scale-free network, with a few countries being the most influential economies in global trade. Accordingly, global integration, measured by network density indicators, decreases much more at high values of trade.

As for Fagiolo et al. (2010), they use a 159-country dataset provided by Gleditsch (2002), which is an expanded version of International Monetary Fund's dataset on reports by member states. They undertake an undirected weighted network approach to study the evolution of the WTN between 1981 and 2000; the undirected nature of the network is justified by the prevalence of reciprocal connections, as also reported by Serrano and Boguñá (2003). They examine trade networks weighted by the value of exports divided by the size (i.e. GDP) of the exporter country. They find that the networks are extremely and increasingly dense, in which almost all trade relationships tend to be reciprocated with similar intensities. They report that trade connections among countries are distributed in a rather homogeneous fashion, whereas their intensity is particularly right-skewed (i.e. heterogeneous); that is, the bulk of countries holds mainly weak (i.e. low value) trade relations, whereas only a selected set of (high income) countries holds numerous and intense relations. Furthermore, not only connections are reported to be homogeneously distributed, but their distribution is found to display some bimodality. They find that the structural properties of the WTN are rather stationary, with an increase in density and reciprocity that suggests that the recent wave of globalization has resulted in an increased number of trade relations with no sizable effect on their intensity. According to their tests, these results are robust to several trade relations' weighting methods.

Barigozzi et al. (2010) use Comtrade data to analyze the topological features of a 162-country WTN and its corresponding 97-commodity-specific networks over the 1992-2003 period. They report that the connectivity of the WTN is mainly achieved through the presence of many weak (i.e. low value) links in commodity-specific networks. Also, they conclude that the low heterogeneity of the

---

[8] The core-periphery network structure (see Craig & von Peter, 2014 and Fricke & Lux, 2015a) differs from the customary core-periphery concept in trade literature. The former is related to networks with a densely connected core and a sparse periphery, in which peripheral elements tend not to transact directly with each other –but through the core. Regarding the latter, the core of world trade consists of countries specialized in capital-intensive and high-tech production, whereas peripheral countries apply themselves to low-valued added, labor-intensive products or unprocessed and raw products (Wallerstein, 1974). In this paper we will refer to the core-periphery in the network structure sense.

distribution of links in the WTN is a sheer outcome of the aggregation of extremely heterogeneous commodity-specific networks. Likewise, other main characteristics of the WTN differ from those corresponding to commodity-specific networks; for instance, the density of the WTN is higher than that of its constituents. About network dynamics, they report that density and reciprocity has increased.

De Benedictis and Tajoli (2013) use International Monetary Fund's trade dataset for six years, corresponding to six decades (i.e. 1950, 1960, 1970 … 2000). They find that the world is still far from being fully integrated, yet full connectedness is already evident at subregional scale. They identify a rising trend in the number of trade links and –thus- in connectedness, and suggest that WTO members have many more trade linkages and are more closely interconnected than nonmembers; therefore, they argue that trade policies do play a role in shaping the trade network. They suggest that WTN's structure has become more complex, with a bimodal and homogeneous distribution of trade connections (as also reported by Fagiolo et al., 2010) that renders characterizations of the WTN as a core-periphery network structure obsolete. They also find that continental subnetworks are more densely connected than the WTN, which may be interpreted as a signal of regionalization of trade. Regarding the dynamics of regional trade, comparing data for years 1980 and 2000, they find that the trade density of some continents (e.g. America, Africa, Oceania) and the WTN has increased, whereas that of Europe and Asia has decreased.

Maeng et al. (2012) use the 1950-2000 dataset provided by Gleditsch (2002). They find that as countries trade to almost all others, the WTN is extremely dense, close to that of a fully connected network. As other authors before them, they report that many weak trading relations coexist with a few strong trading relations. Maeng et al. (2012) implement the *minimal spanning tree* method in order to attain a clearer view of the densely connected WTN, and to identify the dominant trading partners among countries.

Finally, De Benedictis et al. (2013) use the 1995-2010 BACI-CEPII dataset, which is a 178-country variant of Comtrade that uses a reconciliation methodology to reduce the number of missing values. They report that the WTN is characterized by its increasing density and strong heterogeneity, with a particularly right-skewed distribution of links and their weights, presumably in the form of a scale-free network. Regarding the heterogeneity of links, they report that more than 90 per cent of bilateral trade flows are of modest relevance in their contribution to world trade. Also, they report that world trade is dominated by a core group of 17 key players, and those core players correspond to the largest countries. These authors also disaggregate the WTN into several products (e.g. bananas, footwear, crude oil, engines), and they confirm that those networks are heterogeneous as well, with core countries varying in each case.

Our paper enlarges the literature on analyzing the WTN, and contributes in various ways. Firstly, this is the first paper we are aware of that documents the evolution of the WTN including the post-crisis 2008-2009 period, which allows us to examine whether there is evidence of crisis-related structural changes in world trade. Secondly, we examine the 16 sectors reported by Comtrade as the main constituents of the WTN, which allows us to augment the literature on multi-layer trade networks such as Barigozzi et al. (2010) and De Benedictis et al. (2013). Thirdly, unlike most existing literature on the WTN, for instance that Serrano and Boguña (2003), Kali and Reyes (2007) and Fagiolo et al. (2010) reviewed here, we do not filter out trade relations by their value nor we weight them by the size of the exporter or importer. Instead, we keep the dataset in a raw form after discarding all the countries that fail to report consistently during the 1995-2014 period; that is, we attempt to preserve the networks' features and to acknowledge the importance of establishing trade linkages between countries irrespective of their size, while avoiding the potential bias that may arise from keeping non-reporting countries in the dataset. Fourthly, along with traditional visualizations of WTNs by means of graphs, we provide the corresponding *minimal spanning tree* visualization. This alternative method, which reveals the hierarchical structure of the WTN, as in Maeng et al. (2012) and Ospina (2013), not only enabled us to further examine how the WTN has evolved, but also allowed to link our results to prevalent gravity models of international trade referenced above.

3 Methodology and data

Network analysis' basic concepts and notation are presented first, with the corresponding formulae exhibited in Appendix 1.[9] Second, we describe the datasets and the processing procedure implemented in our case.

3.1 Network analysis

The network science research process provides two different paths for understanding the structure of systems: *network analysis* and *network modeling.* As in Börner et al. (2007), the first path is dedicated to describing and understanding an underlying system, focused on capturing the system's structure. The second path attempts to design processes that reproduce empirical data and also serve the purpose of making predictions, focused on model validation.

---

[9] A comprehensive review of the concepts and metrics in network analysis is outside the scope of our paper. We refer the reader to Börner et al. (2007) and Newman (2010).

In this vein, this document employs the network analysis process (i.e. network sampling, measurement, and visualization), with the ultimate aim of studying the structure and evolution of the WTN from 1995 to 2014. We focus on identifying and discussing the main connective features, hierarchical structure, and dynamics of the WTN, along with those of the different networks that compose it according to their classification by trade sector –as classified by Comtrade.

A network represents a system, which is a set of elements that are related by their connections or links. In the case of WTNs the elements –also known as vertexes or nodes- are the countries, and their connections –also known as edges- are given by their exchanges of goods and services, measured by their exports. As the existence of exports from country A to country B does not imply exports from B to A, the WTN is better portrayed as a directed graph (i.e. in which the direction of the edges is relevant); even if there are exports from A to B and from B to A, it is most likely that their value is not equal, thus a weighted direct graph is convenient as well. Also, as there are no exports from a country to itself, the graph should not display self-edges.

The most common representation of a network is the adjacency matrix. In our case, due to the directed nature of the WTN, if n is the number of countries, the adjacency matrix A is a square matrix of dimensions $n \times n$ with elements A_{ij} such that

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

The adjacency matrix is binary, in which a 1 represents the existence of an export from i to j, irrespective of the value of the exports. The weighted adjacency matrix W, with elements W_{ij}, displays the monetary value of the exports from i to j. Graphically, an export from i to j is represented by an arrow or directed edge from vertex i to vertex j, and its width may be used to represent its contribution to the total value of exports.

There are numerous metrics or measures related to network analysis. Due to our aim we focus on those that are most commonly used when studying network's connectivity and local structure, namely density, mean geodesic distance, reciprocity, clustering coefficient, assortativity coefficient, and the distribution of degree and strength.[10] These metrics and their related concepts and notations are presented next, whereas the formulae is presented in Appendix 1.

---

[10] Most metrics intended for characterizing the vertexes (e.g. centrality) are not considered because we do not focus on the role or importance of specific countries in the network.

- Degree ($\mathscr{k}_i$): Based on adjacency matrix A, it corresponds to the number of edges connected to vertex i. In directed graphs *in degree* ($\mathscr{k}_i^{in}$) and *out degree* ($\mathscr{k}_i^{out}$) quantify the number of incoming and outgoing edges, respectively.

- Strength ($\mathscr{s}_i$): Based on the weighted adjacency matrix W, it measures the total weight of connections for vertex i, which provides an assessment of the intensity of its interaction within the network; *in strength* ($\mathscr{s}_i^{in}$) and *out strength* ($\mathscr{s}_i^{out}$) sum the weight of incoming and outgoing edges, respectively.

- Density ($\mathscr{d}$): It measures the cohesion of the network. The density of a graph is the ratio of the number of actual edges ($\mathscr{m}$) to the maximum possible number of edges. Density is restricted to the $0 < \mathscr{d} \leq 1$ range. Networks are commonly labeled as sparse when the density is much smaller than the upper limit ($\mathscr{d} \ll 1$), and as dense when the density approximates the upper limit. An alternative to density for measuring network's cohesion is the average degree of the network; as they convey the same information, but density is bounded to a defined range, we prefer the former. Real-world networks (e.g. biological, social, and technological) are usually sparse.

- Mean geodesic distance (ℓ): Let $\mathscr{g}_{ij}$ be the *geodesic distance* (i.e. the shortest path in terms of number of edges) from vertex i to j. The mean geodesic distance for vertex i (ℓ_i) corresponds to the mean of $\mathscr{g}_{ij}$, averaged over all reachable vertexes j in the network (Newman, 2010). Respectively, the mean geodesic distance or average path length of a network (i.e. for all pairs of vertexes) is denoted as ℓ (without the subscript), and corresponds to the mean of ℓ_i over all vertexes. Real-world networks tend to display what is called the *small-world effect,* corresponding to a short mean geodesic distance irrespective of the size of the network.

- Reciprocity (r): The reciprocity coefficient (r) measures the probability that an edge from i to j is complemented by the reciprocal edge, from j to i. That is, in directed networks, one relation is reciprocal if there are edges in both directions between a pair of vertices; such relation between two vertexes is called a dyadic. Reciprocity can be calculated as the fraction of links for which there is a link in the opposite direction in the network. If $r = 1$ then the network is purely bidirectional (i.e. reciprocal), while if $r = 0$ the network is purely unidirectional.

- Clustering coefficient (c): It corresponds to the property of network transitivity. It measures the average probability that two neighbors of a vertex are themselves neighbors; the coefficient hence measures the frequency with which loops of length three (i.e. a triadic) appear in the network (Newman, 2010). Real-world networks tend to exhibit a large degree of clustering, in the 10 per cent and 60 per cent range (Newman, 2010).

- Assortativity coefficient by degree (a_k): In the case of *assortative mixing by degree* ($a_k > 0$), also known as *homophily*, high-degree (low-degree) vertexes tend to be connected to other high-degree (low-degree) vertexes. In the case of *disassortative mixing by degree* ($a_k < 0$) high-degree vertexes tend to be connected to low-degree vertexes.[11]

- Assortativity coefficient by strength (a_s): In the case of *assortative mixing by strength* ($a_s > 0$) high-strength (low-strength) vertexes tend to be connected to other high-strength (low-strength) vertexes. In the case of *disassortative mixing by strength* ($a_s < 0$) low-strength vertexes tend to be connected to low-strength vertexes and vice versa.

- Degree power-law exponent (γ_k): The power-law distribution of degree suggests that the probability of observing a vertex with k edges obeys the potential functional form $\mathcal{P}_k \propto z k^{-\gamma_k}$, where z is an arbitrary constant, and γ_k is known as the exponent of the power-law. Values in the range $2 \leq \gamma_k \leq 3$ are typical of scale-free networks (Barabási & Albert, 1999)[12], and correspond to a distribution of edges with extremely slow-decaying tails, in which there are a few heavily connected participants and many poorly connected participants, with no typical or representative participant. If $\gamma_k > 3$ the distribution of edges is presumed homogeneous, with rapidly-decaying tails, as in exponential families of distributions (e.g. Poisson, Gaussian), and are normally referred to as random or exponential networks. A graphical comparison of both types of networks, random and scale-free, is presented in Figure 1.

---

[11] Newman (2010) and Jackson (2010) state that core-periphery structures are a common feature of social networks, many of which are found to be assortatively mixed by degree. However, Csermely et al. (2013) and Li et al. (2014) argue that core-periphery is a feature that is related to both assortative and disassortative mixing by degree (i.e. it is not exclusive to one of them), in which other network features (e.g. number of elements) may determine how such relation is resolved. Therefore, we avoid implying the presence of a core-periphery structure based on (dis) assortativity.

[12] Nevertheless, values slightly outside this range are possible and are observed occasionally (Newman, 2010).

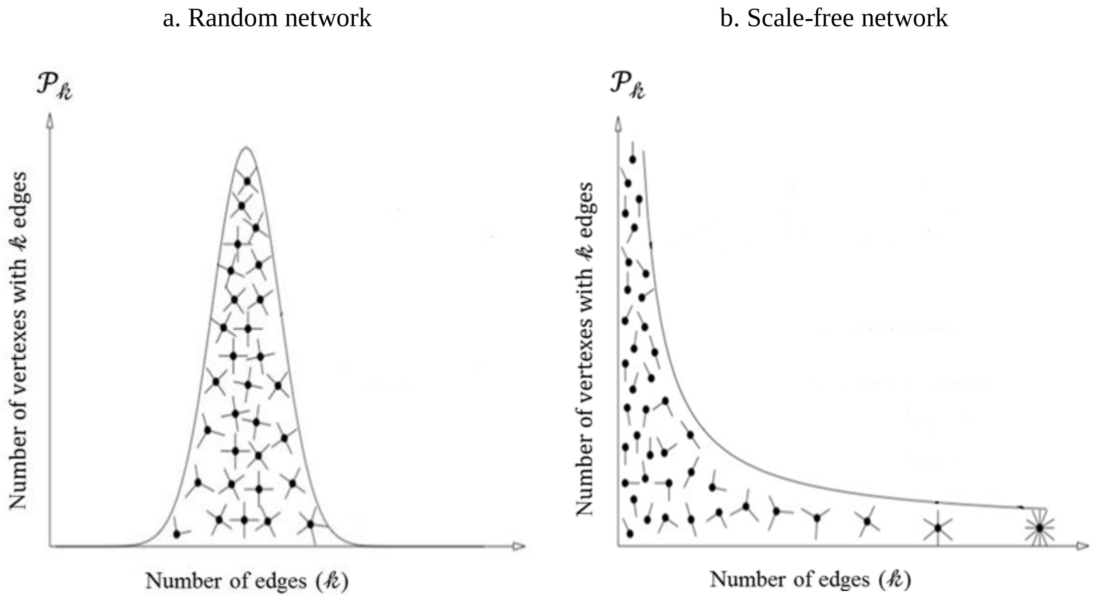


Figure 1. Random and scale-free networks (based on Barabási, 2003). The distribution of edges in the random network (panel a.) is homogeneous (i.e. symmetric, with rapidly decaying tails) in which the average number of edges (i.e. the typical vertex by degree) is easily identified. In the scale-free network (panel b.) the distribution of degree is particularly skewed to the right (i.e. inhomogeneous), with a long and slowly decaying tail, in which the average vertex by degree is not informative about the distribution.

As the power-law distribution of links is an asymptotic property, finding a power-law exponent within the $2 \leq \gamma_k \leq 3$ in a non-large network is indicative of a particularly skewed distribution of links, presumably approximating a scale-free or some other type of inhomogeneous network.[13] Hence, due to the ongoing debate regarding whether empirical networks may be correctly identified and characterized as scale-free (Clauset et al., 2009, Stumpf & Porter, 2012, Fricke & Lux, 2015b), we generalize networks possibly conforming to scale-free features as *inhomogeneous* (Bollobás et al., 2007), and those non-conforming as homogeneous. Paraphrasing Stumpf and Porter (2012), knowledge of whether or not the distribution of links among countries is heavy-tailed (i.e. a few strongly connected, the rest weakly connected) is far more important than whether it can be fit using a power-law.

- Strength power-law exponent (γ_s): The power-law distribution suggests that the probability of observing a vertex with s strength obeys the potential functional form $\mathcal{P}_s \propto z s^{-\gamma_s}$, where z is an

---

[13] The simplest method for estimating the exponent of the power-law (γ) consists of an ordinary least squares (OLS) regression. However, as stressed by Clauset et al. (2009), OLS fitting may be inaccurate due to large fluctuations in the most relevant part of the distribution (i.e. the tail). Therefore, in this paper, we use for all estimations of γ the maximum-likelihood algorithm developed by Clauset et al. (2009).

arbitrary constant, and γ_s is known as the exponent of the power-law. Non-large values of γ_s suggest a particularly skewed distribution of strength in the network. In our case it may be interpreted as evidence of a few intensely connected countries coexisting with a bulk of weakly connected ones.

3.2 Data

We build the WTN based on Comtrade data.[14] We use the value of exports free-on-board.[15] Besides the WTN, we build 16 networks corresponding to the classification of traded goods provided by Comtrade, which comes in the form of a two-digit nomenclature, as shown in Table 1.[16]

The original dataset we work with is annual, starting in 1995 and ending in 2014. As a way of dynamics' analysis for each network, we present the evolution of the topological metrics during the ten biennial periods in the sample (i.e. 1995-96, 1997-98,… 2013-14). Using biennial periods is convenient for two reasons: First, taking into account the non-small number of networks to work with for each period (i.e. 17), working with biennial periods halves the analytical burden while preserving the dynamics of world trade. Second, as there are several non-small or interesting countries for which trade data is not reported for a given year (e.g., Czech Republic, Ecuador, Russian Federation, Saudi Arabia, Ukraine, and Venezuela), building biennial networks enables us to maximize the number of countries to work with, while avoiding downwards bias in connectedness due to missing data.[17] Also, in order to make comparisons between periods straightforward, we keep the network size (i.e. the number of countries) constant by discarding those for which data is unavailable in any period of the biennial dataset.

---

[14] United Nations' Comtrade Database is available for free but by request (http://comtrade.un.org/). The last sector (Codes HS 98-99) is labeled as "Service" by Comtrade, but it corresponds to *products of the United States when returned after* and *other products (not for import to the USA and also…*); therefore, as this does not refer to balance of payments' traded services, hereafter we label it as "Other" to avoid ambiguity.

[15] Free-on-board (FOB) exports corresponds to their value before freight transport, insurance, unloading, and transportation from the arrival port to the final destination.

[16] The two-digit nomenclature classification is a byproduct of the Harmonized System, which is an international nomenclature for the classification of products, which allows participating countries to classify traded goods on a common basis for customs purposes. At the international level, the Harmonized System (HS) for classifying goods is a six-digit code system. The HS comprises approximately 5,300 article/product descriptions that appear as headings and subheadings, arranged in 99 chapters, grouped in 21 sections. Therefore, although we work with 16 different networks to examine world trade, it is possible to work with a more granular classification; of course, at the expense of parsimony.

[17] For this specific purpose we use the average of the value reported in the two years corresponding to the biennial period, or the single value reported in one year in case there is only one year reported.

Table 1
Classifications and Commodity Codes

Network	Codes HS 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.

After this data processing our sample contains 106 countries, in ten biennial periods, with 17 classifications to work with, which add up to 170 networks to examine.[18] Unlike some prior research on the WTN (e.g. Serrano & Boguña, 2003, Kali & Reyes, 2007, Fagiolo et al., 2010), we do not filter out trade relations by their value nor we weight them by the size of the exporter or importer; we attempt to preserve network’s features by acknowledging the importance of establishing trade linkages between countries irrespective of their size.

Under a multi-layer networks’ perspective (Kivelä et al., 2014; D’Agostino & Scala, 2014), the dataset may be conveniently depicted as a multiplex network. In this case each layer consists of a network containing distinct types of links (i.e. trade by sectors in Table 1) but a common type of

---

[18] The number of countries during the 1995-2014 period varies between 163 and 183. After processing, our sample considers 106 countries that reported trade information during all the biennial periods (i.e. a balanced panel), representing about 93.13 per cent of world trade (by value) between 1995 and 2014. Despite our dataset is representative by any standard, some biases may result from limiting the network to consistently reporting countries; however, as it is most unlikely to find an autarkical country, we find that discarding non-reporting countries is a judicious choice. Unlike previous literature, as we work with countries with no missing data only, ours is a positive bias in connectedness among countries. The list of countries considered in (and excluded from) our analysis is reported in Appendix 2.

participants (i.e. countries). The aggregate of the layers is the WTN. Figure 2 depicts the multiplex case for a sample five-country and two-sector hypothetical trade network.

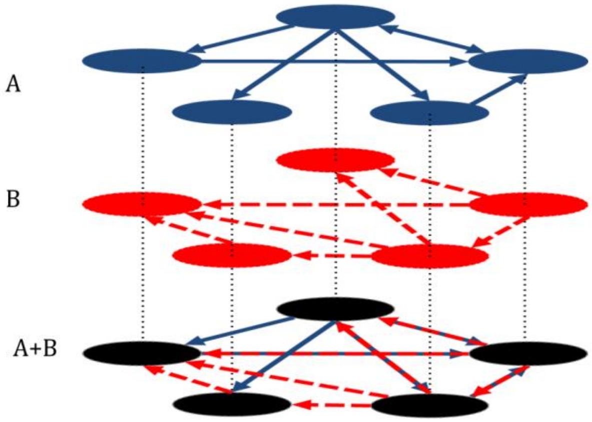


Figure 2. A sample five-country two-sector trade hypothetical multiplex network. Two single-layer networks, A and B, and the multiplex resulting from merging A and B. Vertical lines connecting superimposed vertexes are the countries, whereas each vertex is a role in the corresponding layer. Source: Authors'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

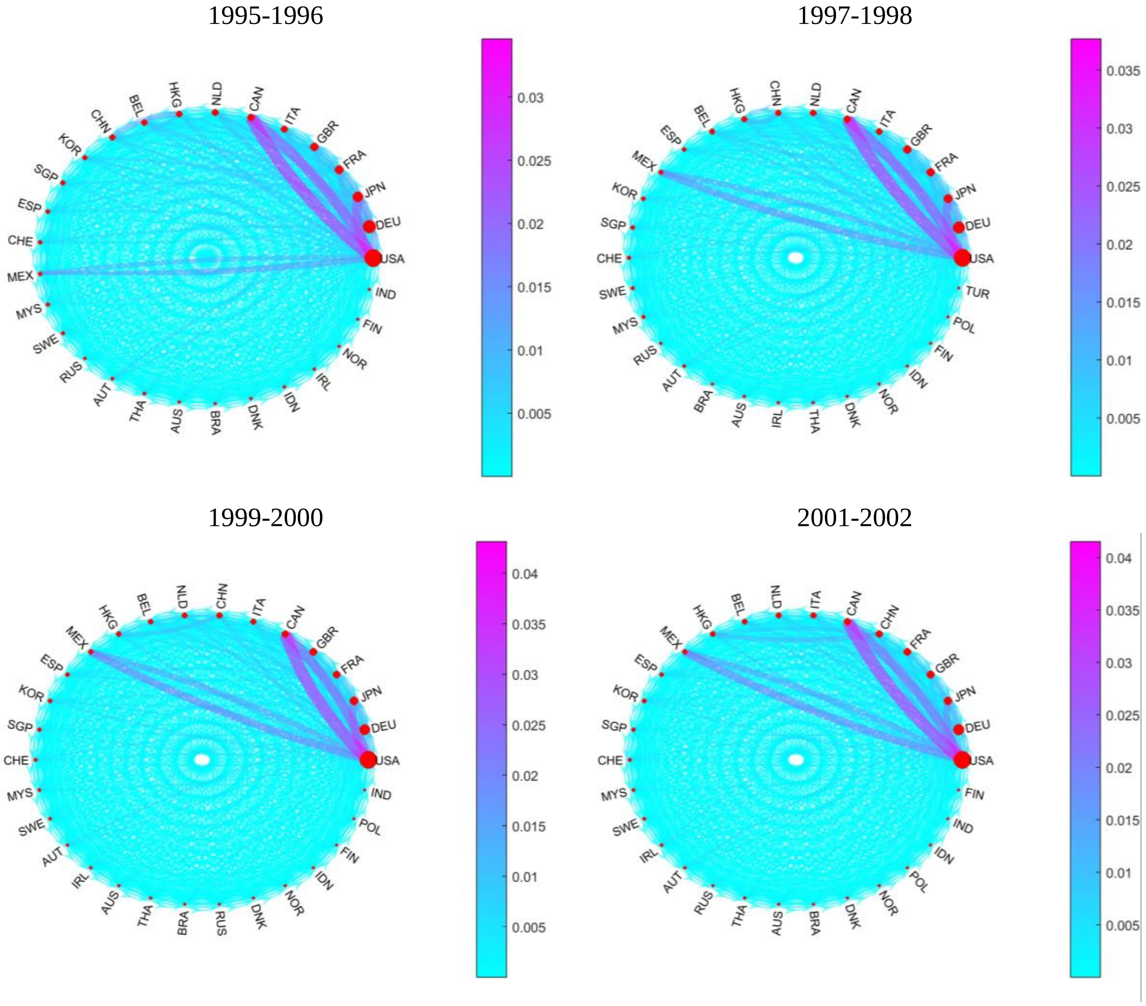
It is important to realize that the connective features of the WTN do not necessarily correspond to a sum or average (either weighted or non-weighted) of the individual features of the different layers it comprises. In this vein, developing representations and models for multi-layer networks is useful in order to increase our understanding of the structure and function of multilayer systems, and can lead to discoveries of new phenomena that cannot be explained by means of a single-layer network framework only (Kivelä et al., 2014).

4 Results

Results are reported in three subsections. The first subsection presents the WTNs, their main structural features, and dynamics. The second unveils and examines WTN's hierarchical structure. The third compares the main structural features of the WTN with those of its constituent networks by sector.

4.1 The world trade network

Figure 3 exhibits all biennial networks corresponding to the WTN from 1995 to 2014. Vertexes correspond to countries, identified by their ISO three-letter code (see Appendix 2). The diameter of each vertex corresponds to each country's contribution to the value of total exports in each biennial period. They are positioned in a circular layout, with the most contributive to total exports in the rightmost location (i.e. the United States in all periods), and those that follow trail in descending order in counter-clockwise form. Despite being concealed in the visualization, the arrows or directed edges between countries follow the direction from exporter to importer, whereas their width and color (see the corresponding color bar) represent their contribution to the total value of exports. Figure 3 displays countries that pertain to per centile 90th of strength (i.e. countries contributing the least are not displayed).



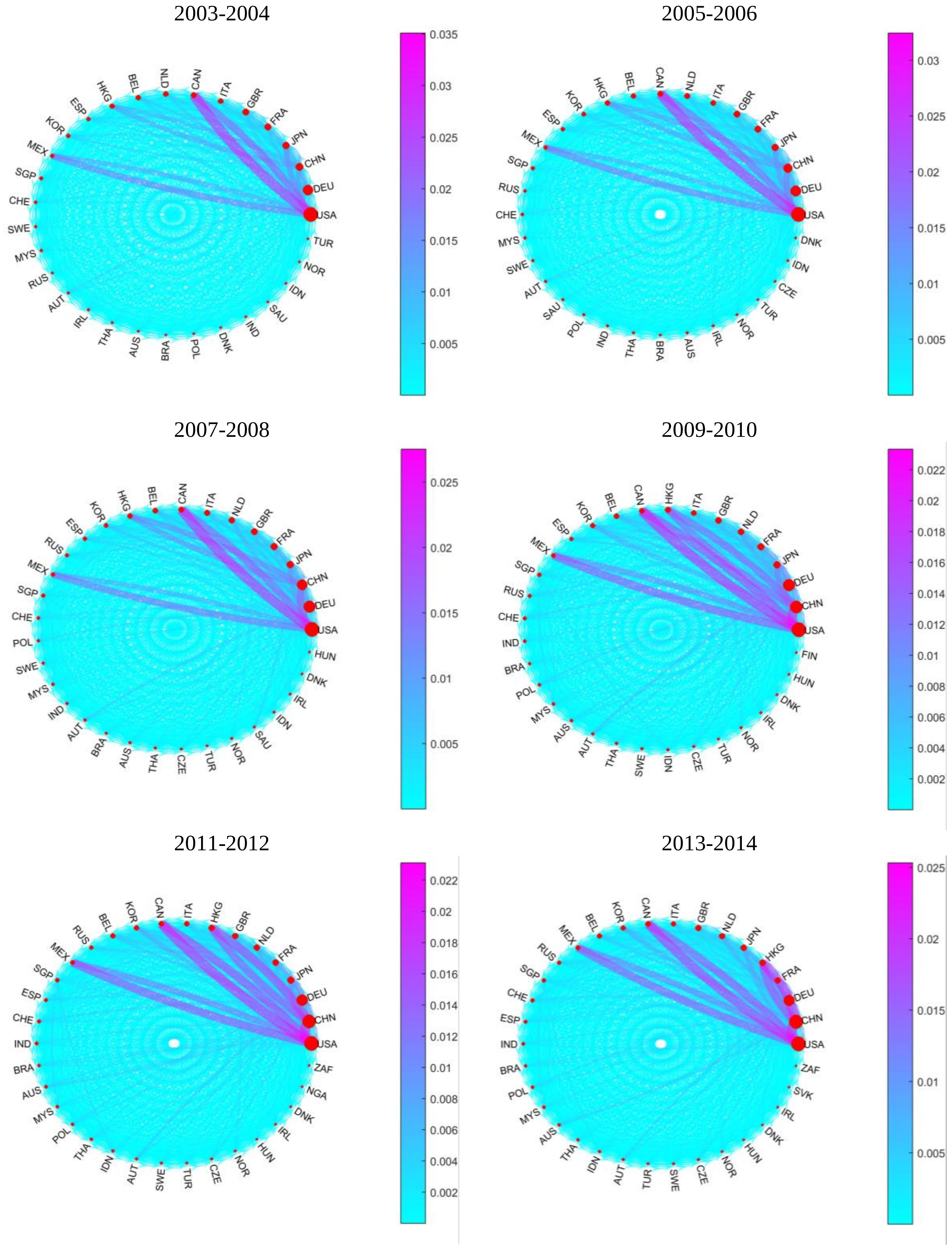


Figure 3. World trade graphs (1995-2014). Vertexes correspond to countries. The diameter of each vertex corresponds to each country's contribution to the value of total exports. They are positioned in a circular layout, with the most contributive to total exports in the rightmost location, and those that follow trail in descending order in counter-clockwise form. Edges are directed and weighted; their width and color (see color bar) corresponds to their contribution to total exports. Only countries that pertain to per centile 90th of strength are displayed. Source: Authors' calculations.

As depicted by vertexes' diameters, the visualization reveals that a few countries concentrate the value of exports in all periods. The United States (USA), Germany (DEU), and Japan (JPN) are the most dominant by diameter in the first six periods, whereas the United States, China (CHN) and Germany are for the last four periods. Correspondingly, those countries concentrate the most intense trade flows (i.e. the weighted edges). Although the intensity of trade flows is rather concentrated, edges appear to be distributed homogeneously among countries, which makes the network particularly dense, with most countries connected to most others in the network.

It is also interesting to realize that there has been a change in the ranking of countries as contributors to the total value of exports –as depicted by the location of vertexes around the circle layout. Perhaps the most evident change in this ranking is the rise of China as one of those countries contributing the most to global trade. In 1995-1996 China was the eleventh exporter (by value), whereas since 2009-2010 it has substituted Germany as the second exporter, only surpassed by the United States. Regarding the other BRICs, namely Brazil (BRA), Russia (RUS), and India (IND), in 1995-1996 they were twenty-third, nineteenth, and twenty-ninth, and in 2009-2010 they were nineteenth, fourteenth, and eighteenth, respectively. Likewise, Hong Kong (HKG) and Mexico (MEX) have increased their contribution to total exports manifestly: they started as the ninth and sixteenth exporter, and ended as the fifth and thirteenth, respectively. Correspondingly, several countries have experienced a setback in their role as contributors to total exports, such as Germany, Japan, France (FRA), Great Britain (GBR), and Canada (CAN), among others. Furthermore, it is rather apparent that the most intense edges are now less concentrated than before: in the first periods the most intense trade relations were dominated by the United States, Germany, Japan, Canada, and Mexico, whereas in the last periods other countries (e.g. China, Hong Kong) became dominant as well.

Table 2 displays the set of selected metrics for the WTN, for each one of the ten biennial periods in the sample. With respect to how cohesively connected countries are, Table 2 shows that density is rather high on average (0.81). From 1995 to 2008 density increased consistently, which shows that new trade relations emerged among the fixed set of countries under analysis. From 2009 to 2014 density changed slightly and without a clear trend, consistent with the change in trade dynamics during and after the 2007-2009 international financial crisis (see World Bank, 2009, Levchenko et al. 2010, Shelburne, 2010, and Chora & Manovab 2012).[19]

Table 2
Topological metrics for the world trade network

Period	d	l	r	c	a_k	a_s	γ_k	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.

The increasing density of the WTN before 2009-2010 is consistent with previous literature. Yet, although literature agrees on the high density of WTNs, our density figures are higher than those reported by other authors. This may be explained by some differences in data processing. As we analyze biennial periods and discard non-reporting countries, it may be the case that our dataset has an upward bias in terms of connectedness, whereas most literature has a corresponding downward bias due to discarding low-value trades and allowing some non-reporting countries into the dataset.

The mean geodesic distance (l), which measures the average number of edges between countries, shows a decreasing trend along the sample. Consistent with the increase in density, the distance between countries decreased markedly between 1995 and 2008; from 2009 onwards the trend is minor and erratic. Also, consistent with the high density, the distance is close to unity, which means that the WTN is close to a fully connected network –as reported by Maeng et al. (2012).

Results in Table 2 also show that the relations in the WTN are reciprocal, with 9 out of 10 trade relations being bidirectional ($r = 0.9$). That is, most countries both export to and import from most of their trade partners. From 1995 to 2014 reciprocity increased from 0.88 to 0.91, and the trend

---

[19] Literature has found that both cyclical and structural factors may explain the slowdown in trade relative to GDP since the crisis (see Boz et al., 2014, Evenett, 2014, ECB, 2014, Armelius et al., 2014, Francis & Morel, 2015, Constantinescu et al., 2015).

matches that of density: increasing from 1995 to 2008, followed by a slight and erratic trend afterward. Furthermore, from a methodological viewpoint, the high level of reciprocity throughout the sample allows to consider the networks as undirected without any loss of topological information (see Serrano & Boguñá, 2003); hence, consistent with findings reported by Fagiolo et al. (2010), the WTN is an extremely symmetric network, which enables us to study it as an undirected network.

Likewise, the clustering coefficient (c) follows a trend similar to that of density. It starts at 0.53 in 1995-96 and ends at 0.66 in 2013-14, with a 0.62 average, and a 0.68 peak in 2007-08. These levels of clustering suggest that it is very likely to find transitive relations (i.e. triads) among countries, and this likelihood has increased parallel to the increase in density; as new relations were built over time, new triads of trade partners were developed. This may be explained by larger world trade openness or new bilateral and multilateral trade agreements. Moreover, by construction, a particularly dense network tends to display high clustering because vertexes tend to share partners.

The assortative mixing by degree coefficient ($a_{\mathscr{k}}$) remains stable over the period under analysis, with an average of 0.58. The evidence of positive and high degree correlation (i.e. assortative mixing by degree) reflects that countries with similar number of connections tend to connect to each other. Nevertheless, it is arguable that network's high density conveys that most countries maintain trade relationships with most other countries, thus it determines the existence of a positive correlation by degree as all countries have a rather similar number of connections.

It is worth noting that some authors (see Kali & Reyes, 2007 and Fagiolo et al., 2010) report that the WTN is disassortative mixing by degree, and they suggest that this validates a core-periphery structure of WTN.[20] In our view, previous results regarding disassortative WTNs are at odds with networks' high density and homogeneity by degree, which –by construction- imply that most edges are among countries with a similar high degree. Moreover, as in a core-periphery network structure vertexes in the periphery should be minimally connected among them (see Craig & von Peter, 2014 and Fricke & Lux, 2015a), WTN's high density may already signal that a core-periphery connective structure is rather unlikely.[21]

Remarkably, the assortativity mixing by strength coefficient ($a_{\mathscr{s}}$) is positive yet close to zero, on average 0.08. This suggests that there is no clear connective pattern driven by the intensity of countries' strength, which means that countries search trading partners irrespective of their

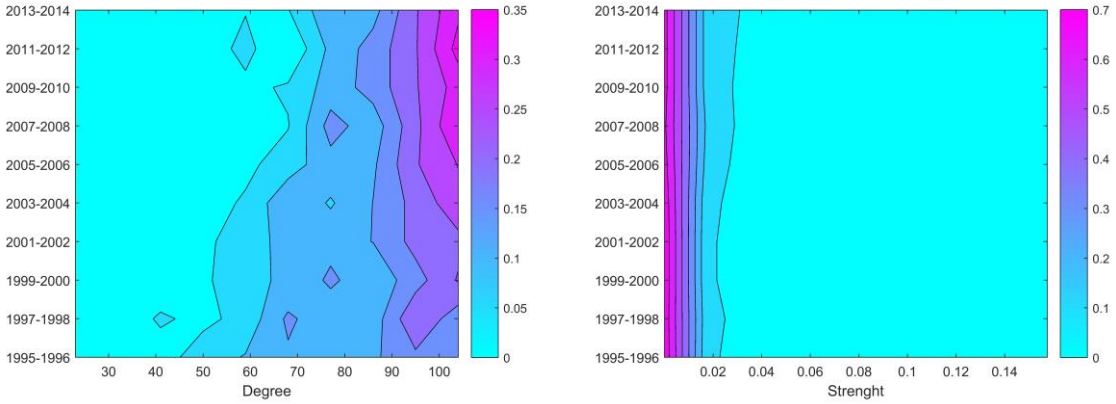
---

[20] However, as stated before, recent literature (see Csermely et al., 2013 and Li et al., 2014) argues that core-periphery is a feature that is not related to disassortative mixing by degree only.

[21] Ospina (2013) exhibits visual evidence (i.e. a blockmodel) that further supports the departure of the WTN from what is expected of a core-periphery network structure.

contribution to the total value of exports. Again, it is arguable that high connectedness among countries drives this result: most countries maintaining a high number of trading partners should break any tendency to establish connections based on the strength of countries. Exports diversification, which aims at increasing the number of trading partners in order to avoid concentrating trading relationships, may explain this result.

Consistent with all prior features of the WTN, Table 2 shows that the distribution of degree among countries is not right-skewed ($\gamma_k \gg 3$), whereas the distribution of strength is particularly right-skewed ($\gamma_s \sim 2$). That is, the expected distinctive real-world connective pattern of a few heavily connected countries and many sparsely connected countries is absent, whereas the intensity of connections is dominated by a few of them. As portrayed in Figure 4, these traits of the distribution of degree (panel a.) and strength (panel b.) are consistent along the sample. The distribution of degree is not right-skewed but left-skewed, with most countries displaying a high number of trading partners (more than 80 out of 105), with a clear trend toward the reduction in the number of weakly connected countries. On the other hand, agreeing with existing literature, the distribution of strength is extremely right-skewed: Most countries display a low contribution to total value of exports, whereas a few countries contribute with figures higher than ten per cent of world trade.



a. Degree

a. Strength

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.

Hence, both the power-law coefficient and the visual inspection of the distribution of degree suggest that the WTN does not fit the scale-free connective structure typical of real-world networks, nor a core-periphery network model. This concurs 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). Once more, it is fair to say that high connectedness among countries drives this result, with most countries sharing similar high numbers of trade partners.

The scale-free connective structure of some real-world networks has been related to *preferential attachment* dynamics (see Barabási & Albert, 1999), in which vertexes tend to connect to strongly connected vertexes. 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. Likewise, a dense and homogeneous distribution of links contravenes a key driver of core-periphery network structures, namely the tendency of elements (i.e. countries) to restrict the set of potential trading partners due to decreasing returns to connectedness (see Hojman & Szeidl, 2008 and Fricke & Lux, 2015a). Furthermore, consistent with the reduction of trade costs and with the benefits inherent to international trade, it is arguable that 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. Consequently, 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.[22]

All in all, attained results enable us to summarize the WTN as particularly dense, reciprocal, compact (i.e. with low distances among countries), clustered, assortative mixing by degree, homogeneous by degree, and inhomogeneous by strength. In this vein, the WTN appears to oppose most real-work networks (e.g. social and financial networks), which tend to share common features such as sparseness and inhomogeneous connective structures. Thus, evidence suggests that scale-free and core-periphery structures seem implausible for characterizing the WTN. And it is fair to say that WTN's connective structure and dynamics may be explained by potential benefits of increasing and diversifying exports outweighing the costs of establishing new trade relations. Unlike some strands

---

[22] Network optimization literature suggests that real-world networks' sparse and inhomogeneous connective structures (e.g. scale-free, core-periphery) may result from a tradeoff between the benefits from connections and their related costs (see Ferrer i Cancho & Solé, 2003 and Hojman & Szeidl, 2008). For instance, financial networks' literature suggests that their sparse and inhomogeneous structure may be driven by a tradeoff, either between maximizing the availability of liquidity and minimizing the exposure to counterparty risk (see Castiglionesi & Wagner, 2013, Castiglionesi & Eboli, 2015, and León & Sarmiento, 2016) or between maximizing linkages to fit counterparties (i.e. preferential attachment) and preserving finite resources (i.e. homeostasis), as in León and Berndsen (2014).

of trading relations literature (e.g. interbank lending[23]), increasing the number of linkages in international trade does not entail a direct increase in risk exposure or monitoring costs, or the depletion of finite resources, therefore high connectedness is a plausible and –potentially- optimal strategy.

4.2 The hierarchical structure of the world trade network

The graphs in Figure 3 and the numerical results in Table 2 are informative of the connective structure of the WTN. However, the dimensionality of the WTN, namely its large number of elements (i.e. countries) and their interactions (i.e. linkages), obscures its hierarchical structure. As highlighted by Maeng et al. (2012) and Ospina (2013) when analyzing the densely connected WTN, it is particularly difficult to identify the important trading partner of a country, or the overall network structure.

A simple yet illuminating method suitable for examining the hierarchical structure of WTN is the *minimal spanning tree* (MST). This dimensionality reduction technique, which consists of choosing the minimal weights (i.e. shortest distances) of a connected system of n vertexes in such a way that the resulting system is an acyclic network (i.e. without loops) with $n-1$ links that minimize the system's weight (León et al., 2014), delivers a filtered version of the original system that retains its most salient features.[24] Hence, the MST is also referred to as the "skeleton" or "backbone" inside the network (Wu et al., 2006).

Figure 5 displays the MST for each biennial period in Figure 3. In our case the MST achieves the backbone of the WTN by minimizing the distance between countries, which is equivalent to maximizing the undirected trade flows between countries.[25] As before, vertexes correspond to countries, identified by their ISO three-letter code (see Appendix 2); again, the diameter corresponds to each country's contribution to the value of total exports. Edges between countries in the MST correspond to the most important trade link for each country –after avoiding loops in the network. Vertexes are positioned in a force layout, which attracts adjacent vertexes and repulses distant ones.

---

[23] Trading relations literature on interbank lending has flourished after the 2007-2008 crisis (see Cocco et al., 2009 and Afonso et al., 2013).

[24] Wu et al. (2006) define the MST as a tree (i.e. a connected, undirected network that contains no closed loops) including all the nodes but only a subset of the links, which has the minimum total weight out of all possible trees that span the entire network.

[25] The undirected version of the world trade network ($\widetilde{W}$) is attained by symmetrizing the weighted adjacency matrix, as described in Fagiolo et al. (2010) and Maeng et al. (2012): $\widetilde{W}_{ij} = 0.5\left(W_{ij} + W_{ji}\right)$. In our case, symmetrizing the world trade network does not entail a loss of information as it is highly reciprocal (see Serrano & Boguñá, 2003 and Fagiolo et al., 2010).

Figure 5 displays countries that pertain to per centile 99th of strength (i.e. those contributing the least are excluded).

The most manifest feature of the first six periods (1995-1996, 1997-1998 … 2005-2006) is that the WTN exhibits a two-group hierarchical structure, with the United States (US) and Germany (DEU) as the leaders of such hierarchy. Geographical clustering is rather evident for these six periods: most countries trailing the United States belong to America and South East Asia & Pacific, whereas most countries trailing Germany belong to Europe & Central Asia.[26] In these six periods Japan (JPN) leads a group that is composed by a handful of countries from East Asia & Pacific, but this group tends to cluster under United States' influence. Moreover, the hierarchical structure in these first six periods is consistent with gravity models of international trade (see references above), which predict that bilateral trade flows are proportional to the economic mass of both countries (i.e. their size measured by GDP) and inversely proportional to the distance between them. In this vein, visual inspection reveals that those countries that lead groups and subgroups from 1995 to 2006 correspond to the largest economies (e.g. United States, Germany, Japan, Great Britain, France), and most of their dangling vertexes correspond to proximate countries (by borders, distance, language, etc.). China (CHN) belongs to the United States group, with Hong Kong (HKG) as its most stable partner.

From 2007 onward the hierarchical structure of the WTN suffers a noticeable shift: China disrupts the two-group hierarchical organization of world trade. In 2007 China moved away from the United States with a group of about ten countries from East Asia & Pacific, including Japan. Afterwards, China preserves a dominant position along United States and Germany, in which these three large countries lead three easily recognizable geographical clusters, namely South East Asia & Pacific, America, and Europe & Central Asia, respectively. It is remarkable that the group led by China has attracted several countries that were close to the United States before 2007, including some that are geographically closer to the United States than to China (e.g. Argentina, Brazil, and Chile). Likewise, some countries have fled the Europe & Central Asia group and clustered with –the more distant- China (e.g. Russia, Ukraine). Some features of this shift in the hierarchical structure contradict geographical clustering. However, this shift in the world trade hierarchy is consistent with gravity models of international trade because, i) China has surpassed Germany as the second largest economy since 2005[27]; ii) the size gap between China and the United States has narrowed; and iii) the distance effect has decreased as trade costs have diminished in the last decades. Also, consistent

---

[26] Not many countries from Middle East & North Africa and Sub Saharan Africa are displayed because of their low contribution to international trade. Thus, we will not refer to these regions when examining the hierarchy.

[27] Measured as the Gross Domestic Product (constant 2010 values, in US dollars). Based on World Bank's World Development Indicators Database, available from http://databank.worldbank.org/.

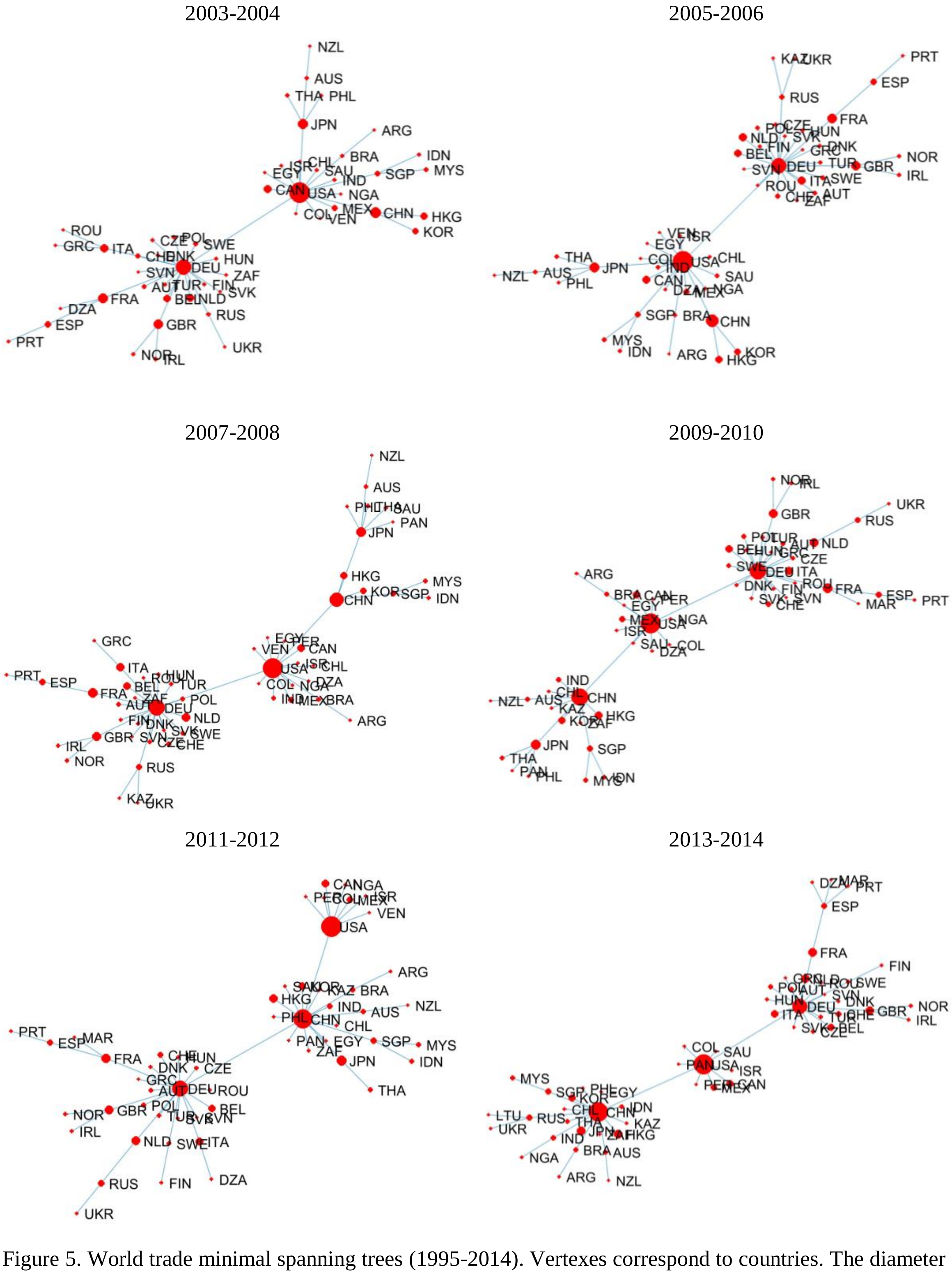
with empirical evidence regarding the strong influence of trading partners' growth on a country's economic growth (see Arora & Vamvakidis, 2005), it is fair to say that fast-growing countries (e.g. China) should be more likely to attract trade flows as well.

1995-1996

1997-1998

1999-2000

2001-2002


2003-2004

2005-2006

2007-2008

2009-2010

2011-2012

2013-2014

Figure 5. World trade minimal spanning trees (1995-2014). Vertexes correspond to countries. The diameter of each vertex corresponds to each country's contribution to the value of total exports. They are positioned in a force layout, which attracts adjacent vertexes and repulses distant ones. Only countries that pertain to per centile 99th of strength are displayed. Source: Authors' calculations.

4.3 The world trade network by sectors

We now study the average topological properties of different trade sectors and compare them to the metrics estimated for the WTN. Table 3 is sorted in descending order by density: the WTN (i.e. the densest) appears in the first row, whereas "Other" (i.e. the sparsest) appear in the last row.

Table 3

Average topological metrics for the world trade network by sectors [a]

Sector	d	l	r	c	a_{k}	a_{s}	γ_{k}	γ_{s}
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_{k}), assortativity coefficient by strength (a_{s}), power-law exponent by degree (γ_{k}), power-law exponent by strength (γ_{s}). [b] Corresponds to the biennial average of world trade network, as reported in Table 2. Source: Authors' calculations.

Table 3 shows that all sectors differ from the WTN. Despite density (d) dynamics throughout the sample are fairly similar for all sectors[28], their levels among sectors are notably lower than that estimated for the WTN. Machinery and electrical sector is the densest network among all examined. Consistent with the lower density, the mean geodesic distance (l) is higher than that reported for the WTN, whereas reciprocity (r) and clustering (c) are high but visibly lower. Also, the power-law exponent of the distribution of degree (γ_{k}) of all sectors differs from that of the WTN, but it is still non-compatible with an inhomogeneous connective structure (e.g. a scale-free or core-periphery network). All sectors exhibit features compatible with an extremely right-skewed distribution of strength (γ_{s}), which suggests that the most intense linkages in all sectors are concentrated in a few countries; it is most likely that the set of countries that concentrate the most intense linkages vary

---

[28] Results by sectors are available upon request.

across sectors, as reported in De Benedictis et al. (2013). Finally, the assortative coefficients by degree and by strength do not differ manifestly from that of the WTN.

All in all, the WTN and its constituent trade sectors do not conform to what is expected from real-world networks, namely because they do not exhibit a sparse and inhomogeneous connective structure. However, concurrent with Barigozzi et al. (2010), it is worth highlighting that the main connective features of the WTN do not correspond to a linear aggregation (e.g. the sum or average) of the connective features of its sectorial constituent networks. For instance, aggregating individual layers with average densities in the 0.27 – 0.65 range yields an overall structure with a 0.81 average density. This phenomenon reminds us that the whole is not the simple sum of its parts in complex systems (Simon, 1962), and highlights the usefulness of developing representations and models for multi-layer networks in order to increase our understanding of the structure and function of multilayer systems (Kivelä et al., 2014). Finally, the sector labeled as "Other", not corresponding to a particular set of products or goods, is the most different with respect to the WTN and the other sectors.

5 Final remarks

Based on data available from 1995 to 2014 we build and visualize the world trade network (WTN), and implement network analysis to characterize and examine world trade. Unlike traditional openness metrics (e.g. trade to GDP ratios), our approach is able to capture the complexity arising from the numerous interactions among countries, hence it allows for a better description and analysis of world trade (see Serrano & Boguñá, 2003 and Fagiolo et al., 2010).

Our main findings come in the form of an updated and enhanced characterization of the connective structure of the WTN. Concurring with Fagiolo et al. (2010), it is fair to state that the WTN is a particularly dense network that consists of a bulk of countries holding numerous weak (i.e. low value) trade relations, and a small set of countries holding both numerous and intense relations. Our results point out that the WTN may be characterized as particularly dense, reciprocal, compact (i.e. with low distances among countries), clustered, assortative mixing by degree, homogeneous by degree, and inhomogeneous by strength. Therefore, we find evidence that the WTN does not conform to the main features exhibited by real-world networks (e.g. social and financial networks). Likewise, due to the particularly dense and homogeneous distribution of linkages, we concur with De Benedictis and Tajoli (2011) and Ospina (2013) regarding the obsoleteness of characterizing the WTN as a core-periphery network. Also, from a network optimization viewpoint, we suggest that the connective structure of the WTN may be explained by potential benefits of increasing and diversifying exports outweighing the costs of establishing new trade relations.

Additionally, based on minimal spanning trees, we reduced the dimensionality problem of the WTN. This enabled us to examine the hierarchical structure of world trade, which unveiled several interesting features. For instance, we identify that the WTN experienced a major shift after 2007-2008, when China disrupted the two-group hierarchical organization of world trade led by the United States and Germany. Due to the rise of China as the second largest economy –surpassing Germany and closing the gap with the United States- and to the declining costs of trade, we suggest that this shift in the WTN hierarchy is consistent with gravity models of international trade.

Finally, we compare the WTN with its constituents, corresponding to the 16-sector classification provided by Comtrade. Concurrent with Barigozzi et al. (2010), we find that the WTN's connective features do not conform to a linear aggregation of sectorial (by product) trade networks. The WTN is denser, more compact, more reciprocal and clustered than its constituents. Nevertheless, despite the differences, all networks here examined agree on the departure from what is usually expected of a real-world network.

Regarding the policy implications, it is worth highlighting that our results provide new insights for analyzing and understanding world and regional trade. For instance, results suggest that liberalization has produced an increasingly dense and homogeneous WTN, but they also suggest that most intense relations are still concentrated in a few countries. Also, due to the shift in the hierarchical structure of world trade after 2007-08 and the evidence of growth spillover effects induced by trade (see Arora & Vamvakidis, 2005), results point out that a revision of countries' trade partners could enhance the benefits of trade –especially for developing economies.

Some avenues for future research are readily available. For instance, examining how some countries and regions have integrated to the WTN may be particularly interesting. In this vein, implementing metrics intended for characterizing vertexes and their role in the WTN (e.g. centrality) may be suitable to evaluate how countries and regions have contributed to the evolution of the WTN. Also, as the 16-sector constituent networks are aggregating a great number of individual products (i.e. approximately 5,300 articles/products), examining and characterizing a more granular dataset may find new features of products' networks that are obscured by the aggregation into broad sectors, and could provide new information regarding how countries or regions contribute to the trade of those products. Likewise, examining the evolution of sectors over time is meaningful for analyzing patterns in trade specialization. Finally, due to the importance of tradable services, and conditional on the completeness of the corresponding datasets, we acknowledge the relevance of examining and analyzing this sector in a forthcoming research project.

6 References

Afonso, G., Kovner, A., & Schoar, A. (2013). Trading partners in the interbank lending market. *Federal Reserve Bank of New York Staff Reports*, *620*, Federal Reserve Bank of New York.

Anderson, J. E. (1979). A theoretical foundation for the gravity equation. *The American Economic Review, 69(1),* 106-116.

Anderson, J. E. & Van Wincoop, E. (2003). Gravity with gravitas: a solution to the border puzzle. *The American Economic Review, 93(1)*, 170-192.

Armelius, H., Belfrage C-J., & Stenbacka H. (2014). The mystery of the missing world trade growth after the global financial crisis. *Sveriges Riksbank Economic Review*, 3, 7-22.

Arora, V. & Vamvakidis, A. (2005). How much do trading partners matter for economic growth? *IMF Staff Papers, 52 (1)*, International Monetary Fund.

Barabasi, A. L. (2003). *Linked: How Everything Is Connected to Everything Else and What It Means for Business, Science, and Everyday Life*. Penguin Group, New York.

Barabási, A.-L. & Albert, R. (1999). Emergence of scaling in random networks. *Science*, *286*, 509-512.

Barigozzi, M., Fagiolo, G., & Garlaschelli, D. (2010). The multi-network of international trade: A commodity-specific analysis. *Physical Review E*, *81(4)*, 046104.

Bergstrand, J. H. (1989). The generalized gravity equation, monopolistic competition, and the factor-proportions theory in international trade. *The review of economics and statistics*, *71(1)*, 143-153.

Bollobás, B., Janson, S., & Riordan, O. (2007). The phase transition in inhomogeneous random graphs. *Random Structures & Algorithms, 31(1)*, 3-122. [doi:10.1002/rsa.20168]

Börner, K., Sanyal, S., & Vespignani, A. (2007). Network Science. *Annual Review of Information Science and Technology*, *41(1)*, 537-607. doi:10.1002/aris.2007.1440410119

Boz, E., Bussière M., & Marsilli, C. (2014). Recent slowdown in global trade: cyclical or structural. VOX CEPR's Policy Portal, 12 November, http://voxeu.org/article/recent-slowdown-global-trade.

Castiglionesi, F. & Eboli, M. (2015). Liquidity flows in interbank networks, *Working Paper Series*, March.

Castiglionesi, F. & Wagner, W. (2013). On the efficiency of bilateral interbank insurance. *Journal of Financial Intermediation, 22*, 177-200.

Chora, D. & Manovab, K. (2012). Off the cliff and back? Credit conditions and international trade during the global financial crisis. *Journal of International Economics*, *87(1)*, 117–133.

Clauset, A., Shalizi, C.R., & Newman, M.E.J. (2009). Power-law distributions in empirical data. *SIAM Review*, *51*, 661-703.

Cocco, J.F., Gomes, F.J., & Martins, N.C. (2009). Lending relationships in the interbank market. *Journal of Financial Intermediation*, *18*, 24-48.

Constantinescu, C., Mattoo A., & Ruta M. (2015). Explaining the global trade slowdown. *VOX CEPR's Policy Portal*, *18*, January, http://voxeu.org/article/explaining-global-trade-slowdown.

Craig, B. & von Peter, G. (2014). Interbank tiering and money center banks. *Journal of Financial Intermediation, 23*, 322-347. [doi:10.1016/j.jfi.2014.02.003]

Csermely, P., London, A., Wu, L.-Y., & Uzzi, B. (2013). Structure and dynamics of core/periphery networks. *Journal of Complex Networks*, *1*, 93-123. [doi:10.1093/comnet/cnt016]

D'Agostino, G. & Scala, A. (2014). *Networks of networks: the last frontier of complexity*. Springer, Cham.

De Benedictis, L., & Tajoli, L. (2011). The world trade network. *The World Economy*, *34(8)*, 1417-1454.

De Benedictis, L., Nenci, S., Santoni, G., Tajoli, L., & Vicarelli, C. (2013). Network analysis of world trade using the BACI-CEPII dataset. *Document de Travail, 2013 – 24*, Centre D'études Prospectives et d' Informations Internationales (CEPII).

Dollar, D. (1992). Outward-oriented developing economies really do grow more rapidly: Evidence from 95 LDCs, 1976-85. *Economic Development and Cultural Change*, *40(3)*, 523-544.

Edwards, S. (1998). Openness, productivity and growth: What do we really know? *Economic Journal*, *108*, 383-398.

European Central Bank – ECB (2014). *Monthly Bulletin*, July.

Evenett, S. (2014). The global trade disorder: new GTA data. *VOX CEPR's Policy Portal*, *13,* November, http://voxeu.org/article/global-trade-disorder-new-gta-data.

Fagiolo, G., Reyes, J., & Schiavo, S. (2010). The evolution of the world trade web: A weighted-network analysis. *Journal of Evolutionary Economics*, *20*, 479-514. [doi:10.1007/s00191-009-0160-x]

Ferrer i Cancho, R. & Solé, R.V. (2003). Optimization in complex networks. In Pastor-Satorras, R., Rubi, J., & Díaz-Aguilera, A. (Eds.), *Statistical mechanics of complex networks (114-125)*. Springer, Berlin-Heidelberg.

Francis, M., & Morel, L. (2015). The slowdown in global trade. *Bank of Canada Review*, Spring, 13-25.

Frankel, J. (2000). Globalization of the Economy. *NBER Working Papers*, *7858,* National Bureau of Economic Research.

Frankel, J. A., & Romer, D. (1999). Does trade cause growth? *American Economic Review*, *89(3)*, 379-399.

Fricke, D. & Lux, T. (2015a). Core-periphery structure in the overnight money market: evidence from the e-MID trading platform. *Computational Economics, 45(3)*, 359-395. [doi:10.1007/s10614-014-9427-x]

Fricke, D. & Lux, T. (2015b). On the distribution of links in the interbank network: evidence from the e-MID overnight money market. *Empirical Economics, 49(4),* 1463-1495. [doi:10.1007/s00181-015-0919-x]

Gleditsch, K. (2002). Expanded trade and GDP data. *Journal of Conflict Resolution, 46 (5)*, 712-724.

Gruss, B. (2014). After the boom – commodity prices and economic growth in Latin America and the Caribbean. *IMF Working Paper, WP/14/154*, International Monetary Fund.

Hojman, D.A. & Szeidl, A. (2008). Core and periphery in networks. *Journal of Economic Theory, 139*, 295-309.

Isard, W. & Peck, M. J. (1954). Location theory and international and interregional trade theory. *The Quarterly Journal of Economics, 68(1)*, 97-114.

Jackson, M.O. (2010). *Social and economic networks*. Princeton University Press, Princeton.

Kali, R., & Reyes, J. (2007). The architecture of globalization: A network approach to international economic integration. *Journal of International Business Studies*, *38(4)*, 595-620.

Kivelä, M., Arenas, A., Barthelemy, M., Gleeson, J.P., Moreno, Y., & Porter, M.A. (2014). Multilayer networks. *Journal of Complex Networks, 519*, 97-125. [doi:10.1016/j.physrep.2012.03.001]

Krueger, A. (1998). Why trade liberalisation is good for growth. *The Economic Journal*, *108*, 1513-1522.

León C. & Sarmiento, M. (2016). Liquidity and counterparty risks tradeoff in money market networks. *Borradores de Economía, 936*, Banco de la República.

León, C. & Berndsen, R. (2014). Rethinking financial stability: Challenges arising from financial networks' modular scale-free architecture. *Journal of Financial Stability, 15*, 241-256. [doi:10.1016/j.jfs.2014.10.006]

León, C., Leiton, K, & Pérez, J. (2014). Extracting the sovereigns' CDS market hierarchy: A correlation-filtering approach. *Physica A*, *415*, 407-420. [doi:10.1016/j.physa.2014.08.020]

Levchenko, A., Lewis, L., & Tesar, L. (2010). The Collapse of International Trade during the 2008-09 Crisis: In Search of the Smoking Gun. *IMF Economic Review, 58(2)*, 214–253.

Li, M., Guan, S., Wu, C., Gong, X., Wu, J., Di, Z., & Lai, C.-H. (2014). From sparse to dense and from assortative to disassortative in online social networks. *Scientific Reports, 4:4861*, [doi:10.1038/srep04861]

Maeng, S.E., Choi, H.W., & Lee, J.W. (2012). Complex networks and minimal spanning trees in international trade networks. *International Journal of Modern Physics: Conference Series, 16*, 51-60. [doi:10.1142/S2010194512007775]

Newman, M.E.J. (2010). *Networks: An Introduction*. Oxford University Press, New York.

Ospina, B. (2013). Impacto de la apertura en la conectividad e integración de colombia en la red mundial del comercio. Tesis de Grado, Facultad de Economía, Universidad del Rosario. [http://repository.urosario.edu.co/bitstream/handle/10336/4545/52810340-2013.pdf]

Serrano, A. & Boguñá, M. (2003). Topology of the world trade web. *Physical Review E, 68*, 015101(R). [doi:10.1103/PhysRevE.68.015101]

Shelburne, R. (2010). The Global Financial Crisis and Its Impact on Trade: The World and the European Emerging Economies, *UNECE Discussion Paper Series, 2010.2*, United Nations Economic Commission of Europe.

Simon, H. (1962). The architecture of complexity. *Proceedings of the American Philosophical Society, 106(6)*, 467-482.

Stiglitz, J.E. (1998). Towards a new paradigm for development: Strategies, policies, and processes. 1998 Prebisch Lecture, UNCTAD, Geneva.

Stumpf, M.P.H. & Porter, M.A. (2012). Critical truths about power laws. *Science, 335*, 665-666. [doi:10.1126/science.1216142]

Tinbergen, J. (1962). An analysis of world trade flows. In Tinbergen, J. (Ed.), *Shaping the World Economy*. Twentieth Century Fund, New York.

United Nations Conference on Trade and Development – UNCTAD (2015). *Evolution of the International Trade System and its Trends from a Development Perspective*.

Wallerstein, I. (1974). *The modern world system I: Capitalist agriculture and the origins of the European world-economy in the sixteenth century*. Academic Press, New York.

World Trade Organization (2013). World Trade Report: Factors Shaping the Future of World Trade.

World Bank (2009). *Global Monitoring Report 2009: A Development Emergency*, The International Bank for Reconstruction and Development / The World Bank.

Wu, Z., Braunstein, L.A., Havlin, S., & Stanley, H.E. (2006). Transport in Weighted Networks: Partition into Superhighways and Roads. *Physical Review Letters, 96*, 148702. [doi:10.1103/PhysRevLett.96.148702]

7 Appendix 1: Network analysis

Table 4
Network analysis formulae

$k_i^{in} = \sum_{j=1}^{n} A_{ji}$ In degree	$k_i^{out} = \sum_{j=1}^{n} A_{ij}$ Out degree
$s_i^{in} = \sum_{j=1}^{n} W_{ji}$ In strength	$s_i^{out} = \sum_{j=1}^{n} W_{ij}$ Out strength
$d = \frac{m}{n(n-1)}$ Density[a]	$\ell_i = \frac{1}{(n-1)} \sum_{j(\neq i)} g_{ij}$ Mean geodesic distance of a vertex
$\ell = \frac{1}{n} \sum_{i} \ell_i$ Mean geodesic distance of a network	$c = \frac{(\text{number of triangles}) \times 3}{\text{number of connected triples}}$ Clustering coefficient
$r_k = \frac{\sum_{ij}\left(A_{ij} - k_i k_j / 2m\right) k_i k_j}{\sum_{ij}\left(k_i \delta_{ij} - k_i k_j / 2m\right) k_i k_j}$ Degree correlation[b]	$c_i = \frac{(\text{pairs of neighbors of } i \text{ that are connected})}{(\text{pairs of neighbors of } i)}$ Local clustering coefficient

Where

A_{ij} is a directed adjacency matrix, $A_{ij} = \left\{ \begin{matrix} 1 \text{ if there is an edge from } i \text{ to } j, \\ 0 \text{ otherwise} \end{matrix} \right\}$
W_{ji} is a directed and weighted adjacency matrix
n is the number of participants in the network
m is the number of edges in the network
g_{ij} is the shortest path (i.e. geodesic distance) between two vertexes i and j

$$\delta_{ij} = \begin{cases} 0 \text{ if } i \neq j \\ 1 \text{ if } i = j \end{cases}$$

---

[a] This corresponds to the density under the assumption of no self-connected vertexes; in the case of allowing self-connections the denominator should be n^2 [b] To compute the strength correlation the k_i and k_j variables outside the parenthesis should be replaced by s_i and s_j, respectively. Source: Authors' design, based on Newman (2010).

8 Appendix 2: countries in the sample

Table 5
Countries in the sample.

Country	ISO3 code	Included (Y/N)	Missing obs.[a]
Aruba	ABW	N	2
Afghanistan	AFG	N	6
Anguilla	AIA	N	5
Albania	ALB	Y	0
Andorra	AND	Y	0
Netherlands Antilles	ANT	N	7
United Arab Emirates	ARE	N	2
Argentina	ARG	Y	0
Armenia	ARM	N	1
Antigua and Barbuda	ATG	N	4
Australia	AUS	Y	0
Austria	AUT	Y	0
Azerbaijan	AZE	Y	0
Burundi	BDI	Y	0
Belgium	BEL	Y	0
Benin	BEN	N	1
Burkina Faso	BFA	Y	0
Bangladesh	BGD	Y	1
Bulgaria	BGR	N	0
Bahrain	BHR	N	2
Bahamas	BHS	N	1
Bosnia and Herzegovina	BIH	N	4
Belarus	BLR	N	1
Belize	BLZ	Y	0
Bermuda	BMU	N	7
Bolivia	BOL	Y	0
Brazil	BRA	Y	0
Barbados	BRB	N	1
Brunei Darussalam	BRN	N	4
Bhutan	BTN	N	4
Botswana	BWA	N	2
Central African Republic	CAF	Y	0
Canada	CAN	Y	0
Switzerland	CHE	Y	0
Chile	CHL	Y	0
China	CHN	Y	0
Côte d'Ivoire	CIV	Y	0
Cameroon	CMR	Y	0
Congo	COG	N	5
Cook Islands	COK	N	3
Colombia	COL	Y	0
Comoros	COM	Y	0
Cape Verde	CPV	N	1

Costa Rica	CRI	Y	0
Cuba	CUB	N	6
Cyprus	CYP	Y	0
Czech Republic	CZE	Y	0
Germany	DEU	Y	0
Djibouti	DJI	N	9
Dominica	DMA	N	1
Denmark	DNK	Y	0
Dominican Republic	DOM	N	1
Algeria	DZA	Y	0
Ecuador	ECU	Y	0
Egypt	EGY	Y	0
Eritrea	ERI	N	9
Spain	ESP	Y	0
Estonia	EST	Y	0
Ethiopia	ETH	Y	0
Finland	FIN	Y	0
Fiji	FJI	N	2
France	FRA	Y	0
Faeroe Islands	FRO	N	2
Micronesia, F.S. of	FSM	N	4
Gabon	GAB	N	2
United Kingdom	GBR	Y	0
Georgia	GEO	Y	0
Ghana	GHA	Y	0
Guinea	GIN	N	2
Guadeloupe	GLP	N	9
Gambia	GMB	Y	0
Guinea-Bissau	GNB	N	8
Greece	GRC	Y	0
Grenada	GRD	N	3
Greenland	GRL	Y	0
Guatemala	GTM	Y	0
French Guiana	GUF	N	9
Guyana	GUY	N	1
Hong Kong (S.A.R.)	HKG	Y	0
Honduras	HND	Y	0
Croatia	HRV	Y	0
Haiti	HTI	N	8
Hungary	HUN	Y	0
Indonesia	IDN	Y	0
India	IND	Y	0
Ireland	IRL	Y	0
Iran	IRN	N	3
Iraq	IRQ	N	7
Iceland	ISL	Y	0
Israel	ISR	Y	0
Italy	ITA	Y	0
Jamaica	JAM	Y	0
Jordan	JOR	Y	0

Japan	JPN	Y	0
Kazakhstan	KAZ	Y	0
Kenya	KEN	N	2
Kyrgyzstan	KGZ	N	1
Cambodia	KHM	N	2
Kiribati	KIR	N	2
Saint Kitts and Nevis	KNA	N	1
Republic of Korea	KOR	Y	0
Kuwait	KWT	N	3
Lebanon	LBN	N	1
Libyan Arab Jamahiriya	LBY	N	8
Saint Lucia	LCA	N	2
Sri Lanka	LKA	N	2
Lesotho	LSO	N	4
Lithuania	LTU	Y	0
Luxembourg	LUX	N	2
Latvia	LVA	Y	0
Macao (S.A.R.)	MAC	Y	0
Morocco	MAR	Y	0
Moldova	MDA	Y	0
Madagascar	MDG	Y	0
Maldives	MDV	Y	0
Mexico	MEX	Y	0
Macedonia (F.Y.R. of)	MKD	Y	0
Mali	MLI	N	1
Malta	MLT	Y	0
Myanmar	MMR	N	9
Montenegro	MNE	N	5
Mongolia	MNG	N	2
Mozambique	MOZ	Y	0
Mauritania	MRT	N	2
Montserrat	MSR	N	2
Martinique	MTQ	N	9
Mauritius	MUS	Y	0
Malawi	MWI	Y	0
Malaysia	MYS	Y	0
Mayotte	MYT	N	4
Namibia	NAM	N	2
New Caledonia	NCL	N	2
Niger	NER	Y	0
Nigeria	NGA	Y	0
Nicaragua	NIC	Y	0
Netherlands	NLD	Y	0
Norway	NOR	Y	0
Nepal	NPL	N	4
New Zealand	NZL	Y	0
Oman	OMN	Y	0
Pakistan	PAK	N	4
Panama	PAN	Y	0
Peru	PER	Y	0

Philippines	PHL	Y	0
Palau	PLW	N	8
Papua New Guinea	PNG	N	5
Poland	POL	Y	0
Portugal	PRT	Y	0
Paraguay	PRY	Y	0
Occupied Palestinian Terr.	PSE	N	6
French Polynesia	PYF	Y	0
Qatar	QAT	N	2
Reunion	REU	N	9
Romania	ROU	Y	0
Russian Federation	RUS	Y	0
Rwanda	RWA	Y	0
Saudi Arabia	SAU	Y	0
Serbia and Montenegro	SCG	N	5
Sudan	SDN	N	1
Senegal	SEN	Y	0
Singapore	SGP	Y	0
Solomon Islands	SLB	N	3
Sierra Leone	SLE	N	7
El Salvador	SLV	Y	0
Serbia	SRB	N	5
Sao Tome and Principe	STP	N	2
Suriname	SUR	N	1
Slovakia	SVK	Y	0
Slovenia	SVN	Y	0
Sweden	SWE	Y	0
Swaziland	SWZ	N	5
Seychelles	SYC	N	3
Syrian Arab Republic	SYR	N	5
Turks and Caicos Islands	TCA	N	3
Togo	TGO	Y	0
Thailand	THA	Y	0
Tajikistan	TJK	N	9
Turkmenistan	TKM	N	8
Timor-Leste	TLS	N	7
Tonga	TON	N	2
Trinidad and Tobago	TTO	N	2
Tunisia	TUN	Y	0
Turkey	TUR	Y	0
Tuvalu	TUV	N	7
United Rep. of Tanzania	TZA	N	1
Uganda	UGA	Y	0
Ukraine	UKR	Y	0
Uruguay	URY	Y	0
United States of America	USA	Y	0
Saint Vincent and the Gren.	VCT	N	1
Venezuela (B.R. of)	VEN	Y	0
Viet Nam	VNM	N	2
Vanuatu	VUT	N	5

Samoa	WSM	N	3
Yemen	YEM	N	4
South Africa	ZAF	Y	0
Zambia	ZMB	Y	0
Zimbabwe	ZWE	N	1

[a] Missing observations correspond to the number of biennials in which no data is reported; those with missing observations were excluded from the sample. Source: Authors' calculations and Comtrade.