Emerging Countries and Trends in the World Trade Network: A Link Analysis Approach

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Abstract

The landscape in the world trade network has changed in last few decades. This paper analyses World Trade Network (WTN) from 1990 to 2016, using the trade data available at the International Monetary Fund (IMF) website and presents the evolution of key players in the network using link analysis properties. Link Analysis analyzes the link strength between nodes of a network to evaluate the properties of the network. The paper uses link analysis algorithm such as PageRank, hubs, and authority to evaluate the strength or importance of nodes in the World Trade Network. A higher PageRank represents higher import dependencies, higher authority scores of a country denotes its significance to import from other hub countries, and a higher hub score indicates a country's significance to export their final product to other authority sectors. The findings show the emergence of Asian countries, especially China, as key players in the world.

Key Words: World Trade Network, link analysis, PageRank, Authority, Hubs

Introduction

The value of global total export in the year 2016 is almost five (4.96) times the value in the year 1990. This fivefold growth in trade value is largely contributed by Emerging Market Economics (EMEs) (Riad et al., 2012). This indicates trade plays a vital role in the national economy as well as in the international economy. In this context, studying world trade from complex network perspectives provides meaningful insights.

World Trade Network (WTN) is weighted directed complex network of countries around the world. In network science, a network is a collection of nodes and links, links are relations between the nodes and, in graph theory, a graph is a collection of vertices and edges, where edges are a relationship between vertices. Graph and Network are terms used interchangeably in this paper. For the WTN nodes are represented by the countries around the world and link represents the relationship between two countries, where the relationship is a flow of trade from one country to another. Study of the WTN applying network and graph theory framework has been growing and could be found in these works of literature (Reyes et al., 2014; Deguchi et al., 2014) (Ermann and Shepelyansky, 2011; Benedictis and Tajoli, 2010).

This paper uses link analysis algorithms to analyze the WTN. Link analysis extracts information from a connected structure like the WTN (Chakraborty et al.). Understanding such connected structure of trade furnish an immense source of information about the world economy, and this paper uses approaches, which was initially adopted to understand the World Wide Web (WWW) (Kleinberg, 1999). Link analysis methods are also used to identify the expert in Social Network (Kardan et al., 2011). This paper Link analysis algorithms HITS (Hypertext Induced Topic Search) (Kleinberg, 1999)and PageRank (Page et al., 1998) algorithms are used to find the importance of countries based on the value export amount from one

country to another. HITS and PageRank are also among the most frequently cited web information retrieval algorithms (Langville & Meyer, 2005). Link Analysis of the WTN gives importance value to the countries of the WTN.

This paper study and analyze the WTN data from 1990 to 2016 as a weighted-directed network. Using the graph framework and applying link analysis perspectives, the paper tries to figure out the emerging countries and their evolution during the study period. The following section describes the link analysis algorithms used in the study and the subsequent section describes and discusses the finding.

Hits Algorithm

HITS algorithm is also known as hubs and authorities algorithm (Kleinberg, 1999). This algorithm gives hubs and authority ranking for each member of the network. Hubs score of a node represents the sum of the authority score of all of the nodes which are pointing to this node. The authority score represents the sum of the hub score of all nodes pointing to this node. Hubs and authorities exhibit a mutually reinforcing relationship: a good hub is a node that points to many good authorities; a good authority is a node that is pointed to by many good hubs (Kleinberg, 1999). In the WTN hubs are countries with large export value and export to good authority countries, and authority is a country with large import values and import from good hubs countries.

Mathematicall, a collection of countries or nodes around the world, and their trade relationship is represented by a graph $G(W, E)$. W represents set of all countries and E represents set of all directed edges or links or all possible exports. Let e_{ij} represents the amount of export from country i to country j. Each country i in the WTN has authority score a_i and hubs score h_i. Let N represents the adjacency matrix of the weighted directed the WTN. In the matrix N each cell represents the value of export from one country to other.

N_{ij} = export value from country i to j

$N_{ij} = 0$ if there is no export from country i to j

A relationship between hubs and authority score and adjacency matrix can be can be expressed in matrix notation as, $a_i^{(k)} = \mathbf{L}^T h_i^{(k-1)}$ and $h_i^{(k)} = \mathbf{L}\ a_i^{(k)}$, where k represents the number of iteration. This paper uses and following algorithm to compute authority and hubs score (Langville and Meyer, 2005).

1. Initialize: with $h^{(0)} = \mathbf{e}$ where $\mathbf{e}$ represents unit column vector. 2. Do

$$a_i^{(k)} = L^T h_i^{(k-1)}$$

$$h_i^{(k)} = \mathbf{L} a_i^{(k)}$$

$$k = k + 1$$

until converges, and normalize $\mathbf{a}^{(k)}$ and $\mathbf{h}^{(k)}$

PageRank

Page rank score gives the importance of each node in the network. Founder of Google Larry Page and Sergey Brin gave the concept of PageRank and Useed it on Google (Page et al., 1998). The notion of PageRank is captured by the rank $r(C)$ of a given country C(Langville and Meyer, 2005).

$$r(C) = \sum_{U \epsilon W_C} r(U)/|U|$$

where W_C = all countries of the world importing to C, and $|Q|$ = number of countries to which U exporting.

This is recursive algoritham. Calculation is performed by calculating vector $\pi_j^T = (r_j(C_1), r_j(C_1), .., r_j(C_n))$, and iteratively computing

$$\pi_j = \mathbf{P}^T \pi_{j-1}$$

until converses. Where is P is goolge matrix defined by

$$\mathbf{P}_{ij} = \alpha V_{ij} + (1 - \alpha)/N$$

where P_{ij} is the element of the google matrix of WTN with N number of nodes. V_{ij} is calulated by normalising to unity all columns of the adjaceny matrix N.

Data

International Monterrey Fund (IMF) Direction of trade (DOTs) data used for this study this study. This paper analyzes DOTs data for the period 1990 to 2016. All available data and countries are used except, countries which don't have any bilateral export or data has not reported due to any reasons by the IMF. Programming language Python and package Networkx(Hagberg et al., 2014) used to analyze the data.

Discussion

This paper examines all non-trivial bilateral trade relationship except a few exceptions. Countries having an only export relationship or only import relationship are excluded from the analysis. In network science terminology, countries with either 0 in-degree or 0 out-degree are removed from the network. The decision of removing such nodes will help to eliminate the problems of dangling nodes and dangling links (Chakraborty et al.; Page et al., 1998; Ermann, 2015; Ermann and Shepelyansky, 2011). Dangling nodes have zero out links and dangling links are links which point to some node or country that have zero out-link(Langville and Meyer, 2005; Page et al., 1998). The following section discusses the result of the application of link analysis algorithms to the WTN.

PageRank

According to PageRank algorithms, each country can be given a PageRank score, which shows the country significance in the WTN (Langville & Meyer, 2005). PageRank score of all countries sums up to 1 and this score lies between 0 and 1, 0 being lest influential. Figure 1 shows the PageRank score of 10 countries, which have the highest PageRank score in the year 2016, for the years 1990 to 2016. In the context of trade network, PageRank score measures the importance of a country in terms of the value of export it receives. The figure shows the USA has the highest PageRank score throughout the study period, with major ups and downs. Germany PageRank has a decreasing trend, with the sign of an upward trend from 2013. PageRank score of China shows higher variability among all. China had lowest PageRank importance during the beginning of the study period (1990) and second highest PageRank during the end of the study period (2016). A sharp increase in PageRank importance of China started from 2000 and continue for the rest of the decade. China became a member of World Trade Organization (WTO) at 2001, making its domestic market open to international Trade. Whereas, PageRank scores of the other 7 countries shows decreasing trend. Notably, PageRank score of these seven countries started conversing towards one point from the beginning of this decade. As the sum of page rank score of all nodes in the network or graph is one, increase in score of one country will affect the scores of other countries.

Heatmap 2 Figure shows the correlation of the PageRank score between 10 countries. The figure shows that PageRank score of China and Hong Kong are moving together. While China and Hong Kong scores

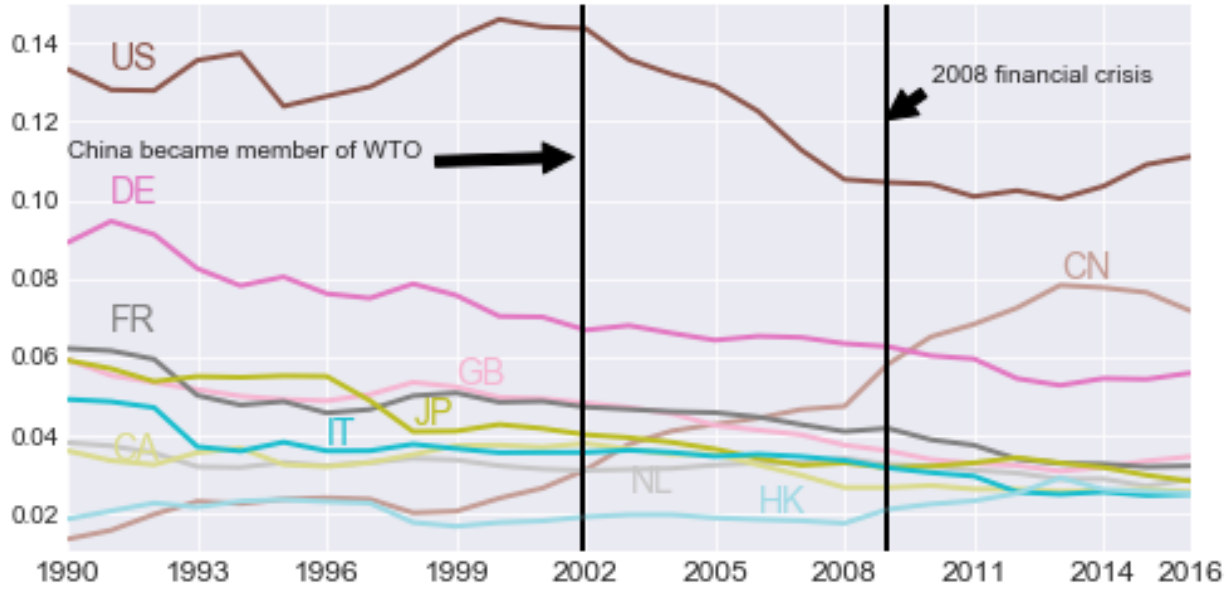

Figure 1: Evolution of PageRank score. Abbreviations are, US = United States, DE= Germany, FR France= , CN = China, GB = Great Britain, IT = Italy, JP = Japan, CA = Canada, NE = Netherlands , HK = Hong Kong

are moving in opposite direction of other eight countries. From 2001 to 2013 correlation between PageRank importance of China and USA is highly negatively correlated as much as 0.91. Similarly, from 2013 to 2016 China and USA has a high negative correlation, while the score for both countries has changed the direction, China's score is decreasing and that of USA is increasing. China's rank score is negatively correlated with not the only USA but all other 8 countries except Hong Kong. Last decade shows a strong negative correlation between PageRank score of USA and China. This shows that in the last decades, the importance of China, as indicated by PageRank, has been increasing, at the same time when the importance of all other countries has been decreasing.

Hubs

In hyperlinked environments such as World Wide Web and the WTN, a hub is a node which has may outgoing links or points to many other nodes. Hubs score represent the importance of a country from the perspectives of its strength and volume of trade export to other countries in the WTN. If a country is a major exporter to a major importer country, then the country will have a higher hubs score. Figure 3 shows the time series plots of hubs score of ten countries from 1990 to 2016. Selected ten countries to have the highest hubs score in the year 2016. With historic economic reform in 1979 and subsequent accession to the World Trade Organization China emerged as a major exporter country or hubs in the WTN (Deguchi et al., 2014). Noticeably, China's hub score has been increasing throughout the study period and emerged as main export nations or hub. Canada, Japan, Mexico, and the USA are major hubs in WTN besides China. The figure shows variability in Hubs score at the beginning of study period during 1990's and less variability during the end of study period. The overall picture shows converging Hubs score for all countries except China. As the hubs score of all countries sums to one, increase in hub score of China resulted in a decrease in hub score of other countries.

Heatmap Figure 4 shows a correlation of hubs score of ten countries for the last twenty score years. Hubs represent a country from where most of the other countries import goods. Data shows hubs score China,

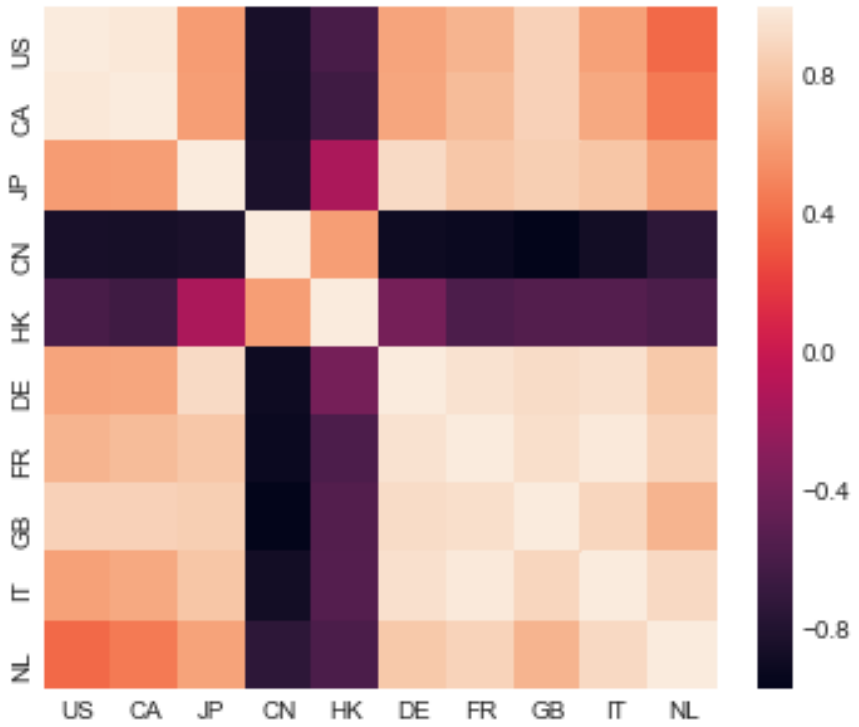

Figure 2: Heatmap of correlation of PageRank score. Abbreviations are, US = United States, DE= Germany, FR France= , CN = China, GB = Great Britain, IT = Italy, JP = Japan, CA = Canada, NE = Netherlands , HK = Hong Kong

a major hub in the WTN is positively correlated with only with Mexico and South Korea, is negatively correlated with other seven countries. EU countries Germany, France, and GB has a very high positive correlation among themselves and also with Japan.

Authority

According to HITS algorithms of Kleinberg, valuable and important pages are pointed by many pages and they are called authority page(Ding et al., 2004). Similarly, in the context of world trade, an authority country is one which has large imports from major hubs countries. Figure 5 shows Authority score. High authority score for a country suggests, the high value of export from countries with the high hubs score. The USA has highest Authority score throughout the study period with pronounced upward and downward trends as well. Which makes the USA a major importer or authority in the WTN. Highest authority score of USA is also related to the fact that the USA is a major exporting destination for countries with higher hubs score. The figure shows China, Japan, Canada, and Mexico has higher hubs score and USA import most of the goods from these countries. Moreover, high authority score of Hong Kong is also explained by the fact that Hong Kong is one of the major exporting destination of China, a country with high hubs score

Figure 6 shows the authority score correlation Heatmap matrix for the top ten countries on the basis of the authority score. Heatmap depicts the high negative correlation between China's authority score to that of Netherland, Great Britain, Germany, and Canada. Which shows the authority score of later countries is moving together but in the opposite direction of the authority score of China.

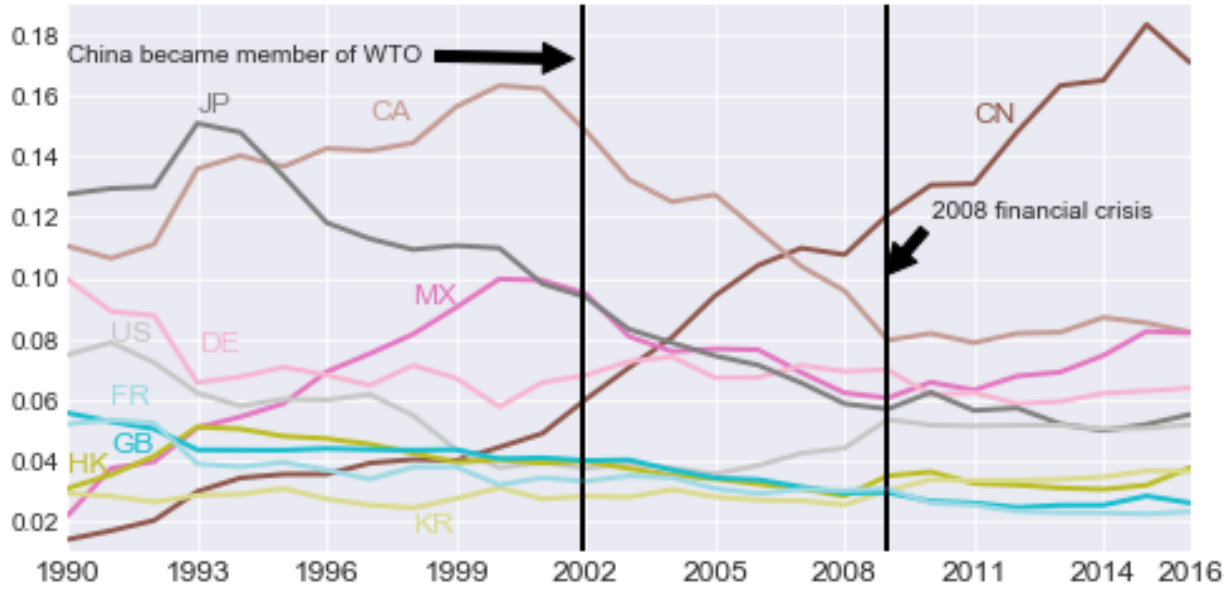

Figure 3: Evolution of Hub score. Abbreviations are, US = United States, DE= Germany, FR France= , CN = China, GB = Great Britain, IT = Italy, JP = Japan, CA = Canada, NE = Netherlands , HK = Hong Kong

Conclusions

In conclusion link analysis algorithms, PageRank and HITS algorithms initially used to rank the importance of web page, are also useful and meaningful to study the comparative importance of countries in the hyper-linked structure of World Trade Network. PageRank score, which is successful to identify the significant page, has been able to capture the importance of countries in the WTN. Similarly, hubs and authority score has been able to capture the importance of countries in the WTN. Some Asian countries have emerged as a major trade center from the perspective of both import and export, and this fact is easily captured by PageRank and Hubs scores.

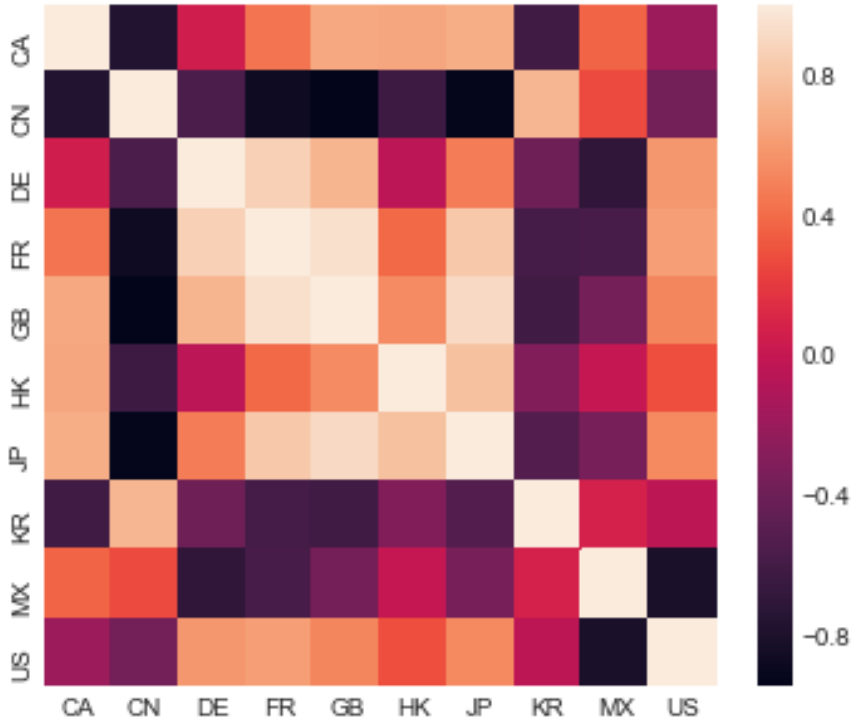

Figure 4: Heatmap of correlation of hubs score. Abbreviations are, US = United States, DE= Germany, FR France= , CN = China, GB = Great Britain, IT = Italy, JP = Japan, CA = Canada, NE = Netherlands , HK = Hong Kong

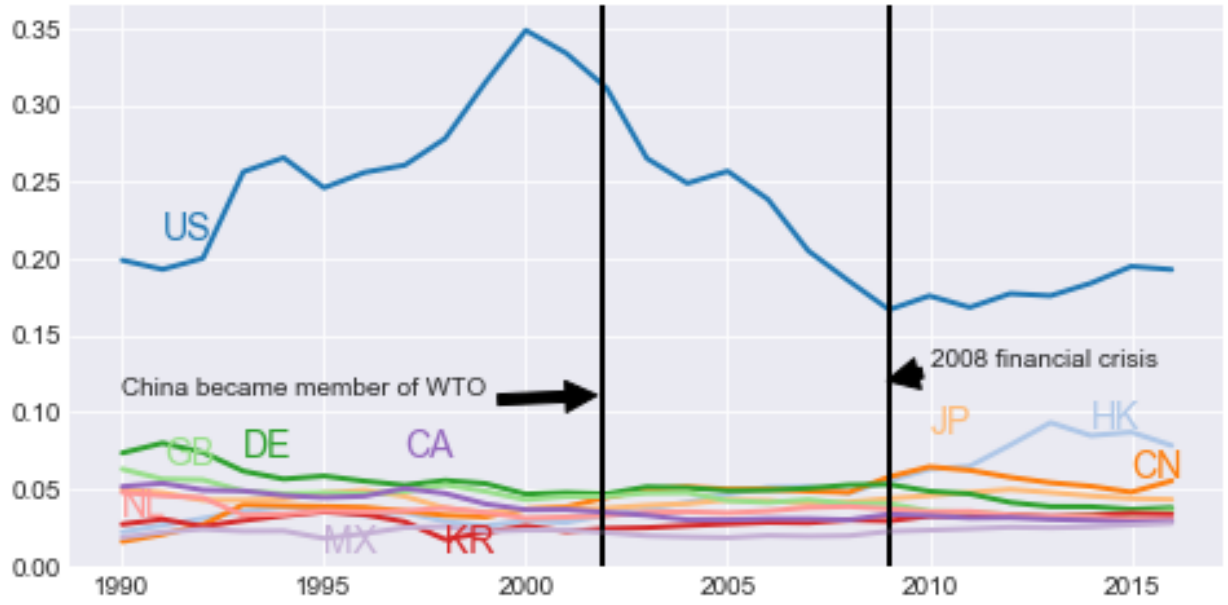

Figure 5: Evolution of Authority score. Abbreviations are, US = United States, DE= Germany, FR France= , CN = China, GB = Great Britain, IT = Italy, JP = Japan, CA = Canada, NE = Netherlands , HK = Hong Kong

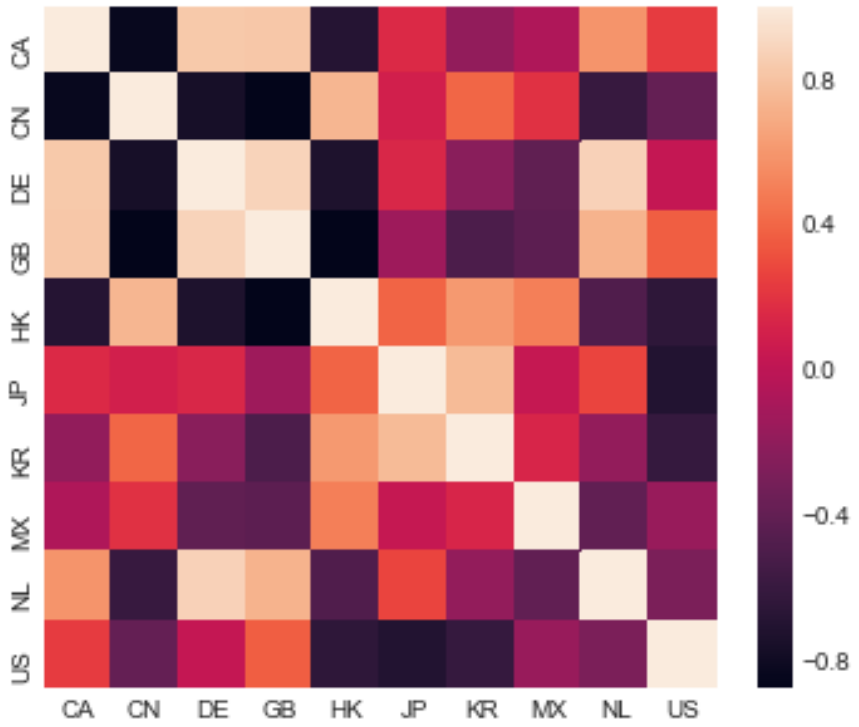

Figure 6: Heatmap of correlation of authority score. Abbreviations are, US = United States, DE= Germany, FR France= , CN = China, GB = Great Britain, IT = Italy, JP = Japan, CA = Canada, NE = Netherlands , HK = Hong Kong

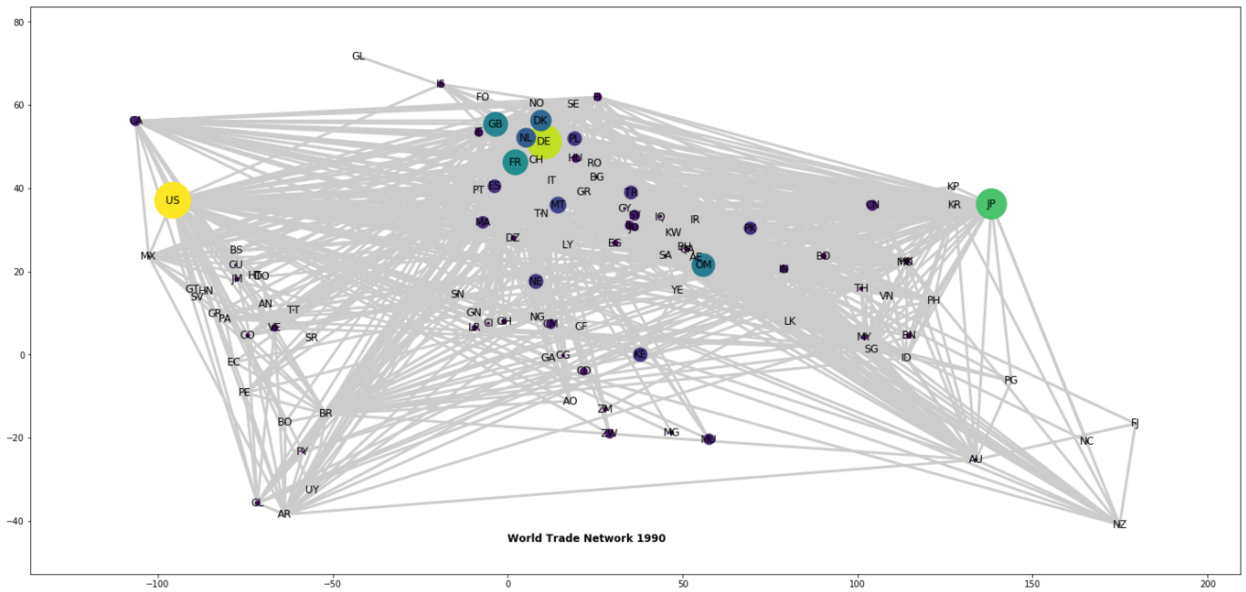

Figure 7: The World Trade Network in 1990. USA (Yellow) and Japan (Green) are major exporting countries. Similarly, Great Britain, France Germany (DE) are other major exporting European countries.

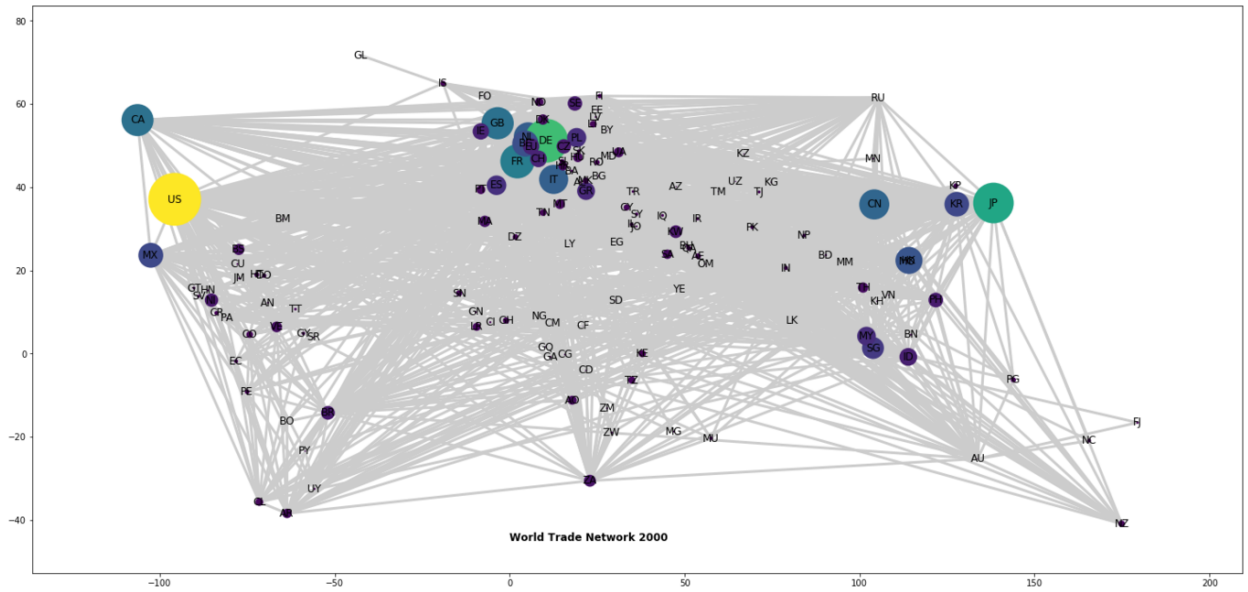

Figure 8: The World Trade Network in 2000. USA (Yellow) and Japan (Green) are major exporting countries. Similarly, Great Britain, France Germany (DE) are other major exporting European countries.

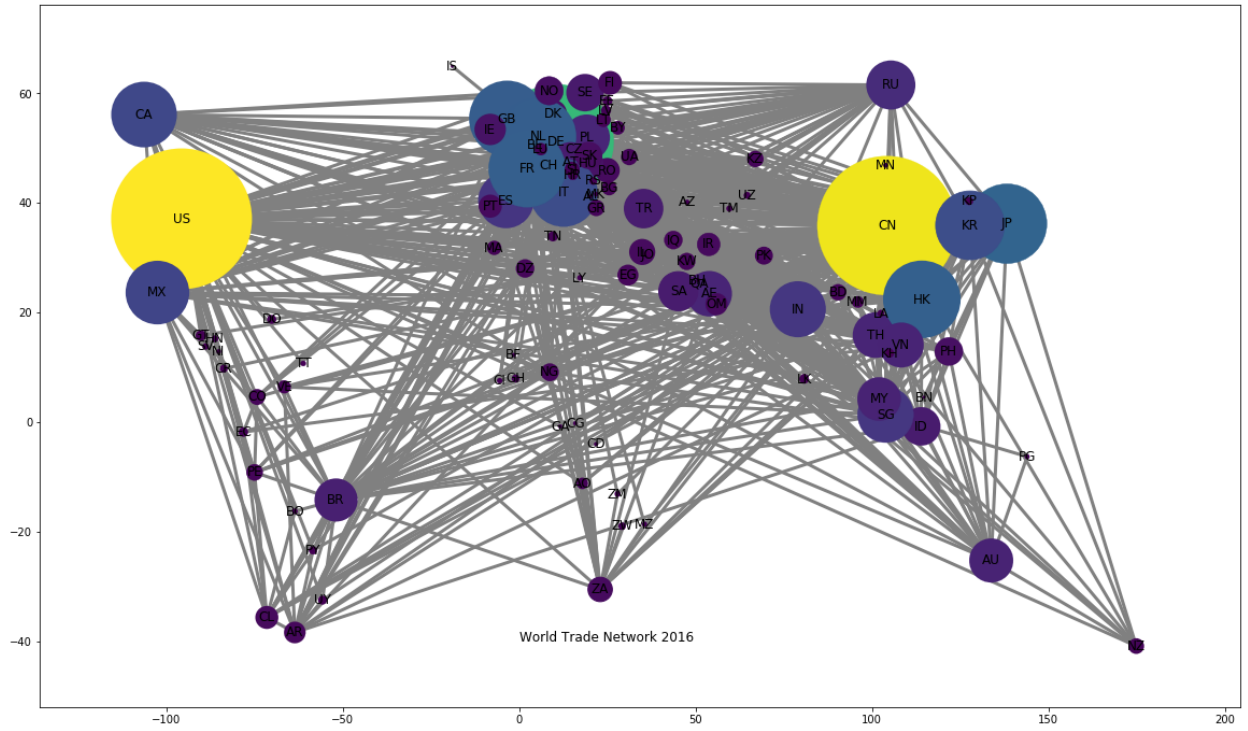

Figure 9: The World Trade Network in 2016. USA (Yellow) and China (Green) are major exporting countries. Similarly, Great Britain, France Germany (DE) are other major exporting European countries.

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