Trading Network Analysis of Economies using AIS Data

Network Analysis:

Network analysis is the study of relationships and interactions among entities (nodes) in a network, and the patterns that emerge from these connections. By studying networks, we can understand how entities interact, identify key actors or nodes, and uncover emergent properties that impact various fields such as social sciences, transportation, economics, and more.

Network analysis of AIS data in the context of trading among countries involves examining the relationships and connections between countries based on their shipping activities. It helps to uncover patterns, trade flows, and key actors in the global trading network, enabling a deeper understanding of the dynamics, efficiency, and interdependencies within the international trade system. By analyzing shipping networks, we can gain valuable insights into trade routes, market access, and the economic relationships between countries.

In the context of our AIS Data Network Analysis.

- Nodes: Represent countries in the context of trade.
- Edges: Represent connections or relationships between countries.
- Networks: Depict the overall structure of trade relationships.

Centrality Measures in Network Analysis:

Centrality measures are a set of metrics used in network analysis to identify the most important nodes or actors within a network. These measures are important because they provide insights into the structure and function of a network, which can help researchers, economists, policy makers, and understand how information or resources flow through the network.

- Degree Centrality: Degree centrality in a trading network measures the number of direct trading partners a country has. It helps in identifying countries with the highest number of trading relationships.

$$\text{Degree Centrality} = \frac{\text{Number of Connections for a Node}}{\text{Total Number of Nodes} - 1}$$

- Closeness Centrality: Closeness centrality in a trading network quantifies how easily a country can access other countries in terms of trade. It helps in identifying countries with efficient access to trading partners and resources.

$$\text{Closeness Centrality} = \frac{1}{\sum \text{of Shortest Path Lengths from the Node to all Other Nodes}}$$

- Betweenness Centrality: Betweenness centrality in a trading network identifies countries that serve as intermediaries or facilitators of trade flows between other countries. It helps in identifying countries that act as intermediaries or bridges in trade flows.

$$\text{Betweenness Centrality} = \frac{\sum\left(\frac{\sigma(s,t)}{\sigma(s,t,v)}\right)}{(N-1)(N-2)}$$

- Eigenvector Centrality: Eigenvector centrality in a trading network captures the influence of a country based on its connections to other influential trading partners. It helps in identifying countries with connections to other influential trading partners.

$$\text{Eigenvector Centrality} = \text{Normalized Eigenvector of the Adjacency Matrix of the Network}$$

Data Processing Methodology:

1. Raw AIS data containing ship positions and identification details was collected.
2. The data underwent cleaning and filtering to include specific ship types, such as 'General Cargo', 'Tanker', and 'Passengers'. This filtering ensured focus on relevant ship categories for analysis.
3. Relevant attributes, including the year, month, country, next country, and ship count, were extracted from the filtered data. This extraction provided essential information on ship movements between countries.
4. Criteria were applied to ensure data accuracy, such as requiring vessels to spend at least 1 hour in the port to be included in the analysis. This criterion helped exclude transient or short-term ship visits.
5. Vessel movements were tracked using a unique identification system based on the International Maritime Organization (IMO) and Maritime Mobile Service Identity (MMSI) numbers. This approach ensured consistent vessel tracking over time, mitigating issues related to changing MMSI numbers.
6. The dataset was refined by selecting MMSI numbers from individual ships that had sent multiple signals during a single movement. This selection focused on actively participating ships, avoiding noise or inactive vessels.

The resulting dataset was structured with columns such as 'Year', 'Month', 'High-Level Category' (e.g., 'General Cargo', 'Tanker', 'Passengers'), 'Country', 'Next_Country', and 'Count'. This dataset formed the foundation for conducting network analysis, enabling insights into trading relationships and patterns between countries based on ship movements.

Results:

Degree Centralities of Major Trading Countries:

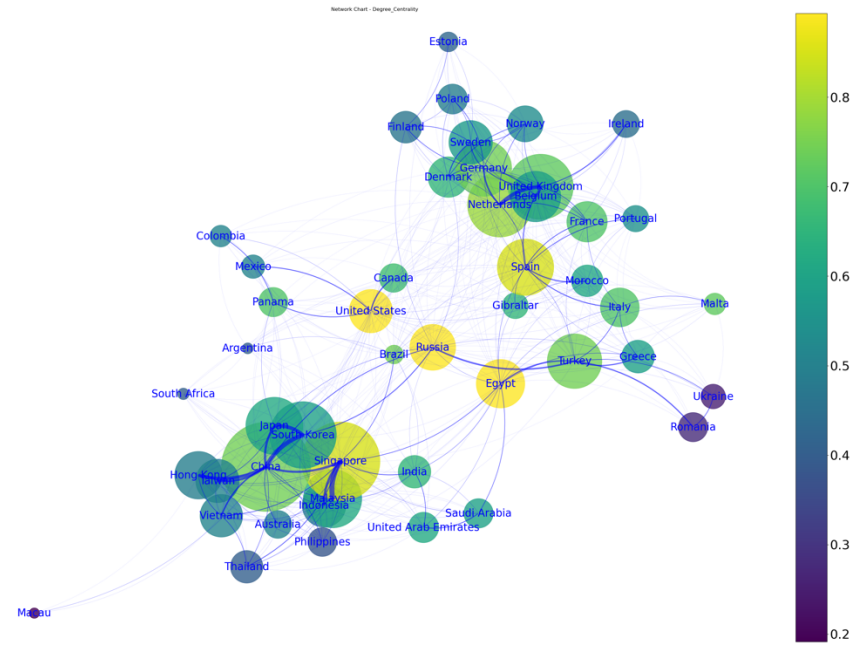


Fig 4.1. The generated network chart represents the trade relationships between countries, with node size indicating the total vessel movement and node color representing the Degree Centrality

Country Importance: The countries with higher degree centrality values indicate a greater number of connections with other countries in the network. United States, Russia, Singapore, and China have the highest degree centrality values, suggesting they have extensive trade relationships and connections with other countries. This implies that the United States, Russia, Singapore, and China has the most extensive network of trade relationships with other countries, making it a key participant in global trade dynamics.

Intermediary Role: The betweenness centrality measure highlights the extent to which a country acts as a bridge or intermediary between other countries in the trade network. Egypt, Russia, Singapore, and United States have the high betweenness centrality values, suggesting they act as intermediaries or bridges between other countries in trade flows. This suggests that these countries play crucial roles in facilitating trade flows and fostering connections between other nations.

Interestingly, the analysis reveals that China, despite having the highest total vessel movements, does not occupy the top position in terms of degree centrality. However, China does feature in the top 10 countries for betweenness centrality, indicating its role as an intermediary or bridge in trade flows between other countries. This suggests that while high total vessel movements are important, they do not necessarily translate into being centrally positioned within the network. This observation is further supported by the inclusion of countries like the UK, Korea, and China in the list of countries with very high total vessel movements but not ranking as highly in terms of centrality.

Betweenness Centralities of Major Trading Countries:

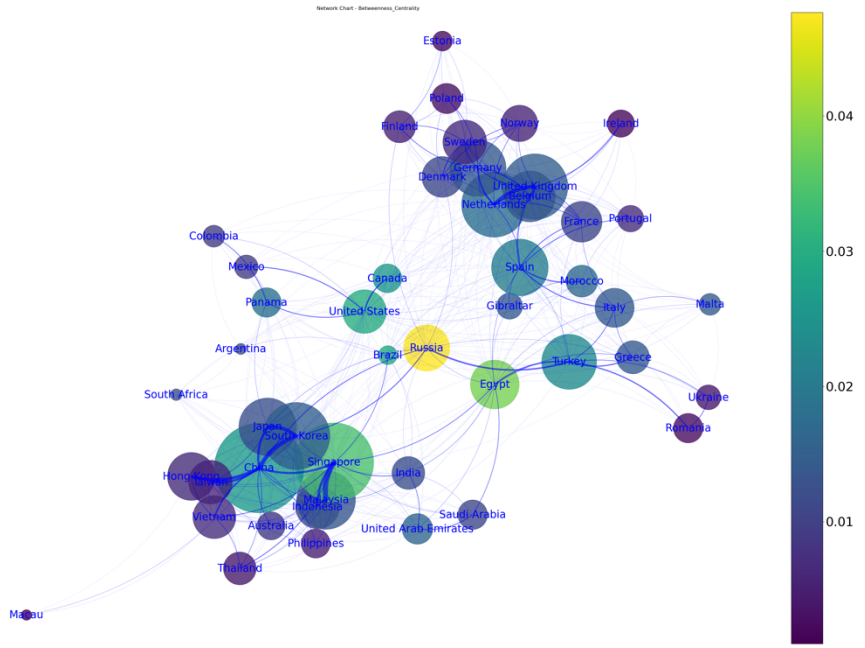


Fig 4.1. The generated network chart represents the trade relationships between countries, with node size indicating the Total Vessel Movement and node color representing the Degree Centrality

The chart here highlights the countries that play important intermediary roles in the trade network, with larger nodes indicating higher trade volumes and darker colors signifying greater influence as intermediaries.

Closeness Centralities of Major Trading Countries:

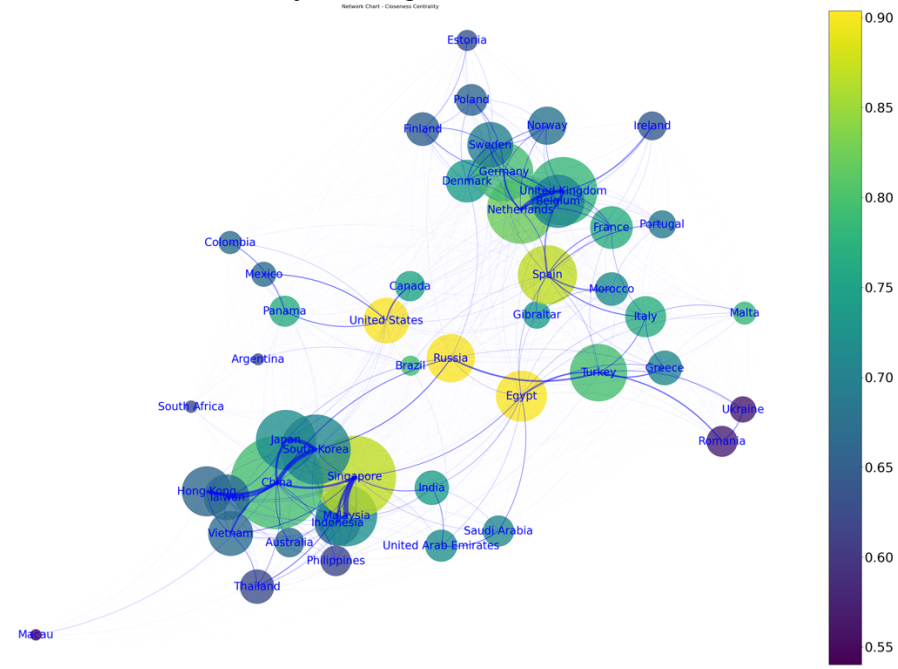


Fig 4.3. The generated network chart represents the trade relationships between countries, with node size indicating the total vessel movement and node color representing the Closeness Centrality

Efficient Access: Closeness centrality provides insights into a country's accessibility and its average distance to reach other countries in the trade network. Egypt, Russia and Spain demonstrate high closeness centrality, indicating that they enjoy efficient access to trading partners and resources. These countries benefit from shorter distances to other markets, enhancing their potential for economic integration and favorable trade relationships. Efficient access enhances their competitive advantage and supports their positions as key players in global trade.

Influence: Eigenvector centrality measures a country's influence based on its connections to other influential countries in the trade network. In our analysis Spain Russia, Singapore, and Netherlands have the high eigenvector centrality values, suggesting that these nations have strong connections with other influential trade partner, amplifying their impact on trade dynamics. Their influence extends beyond their direct connections, enabling them to exert considerable influence on trade flows and shaping global trade patterns.

Eigenvector Centralities of Major Trading Countries:

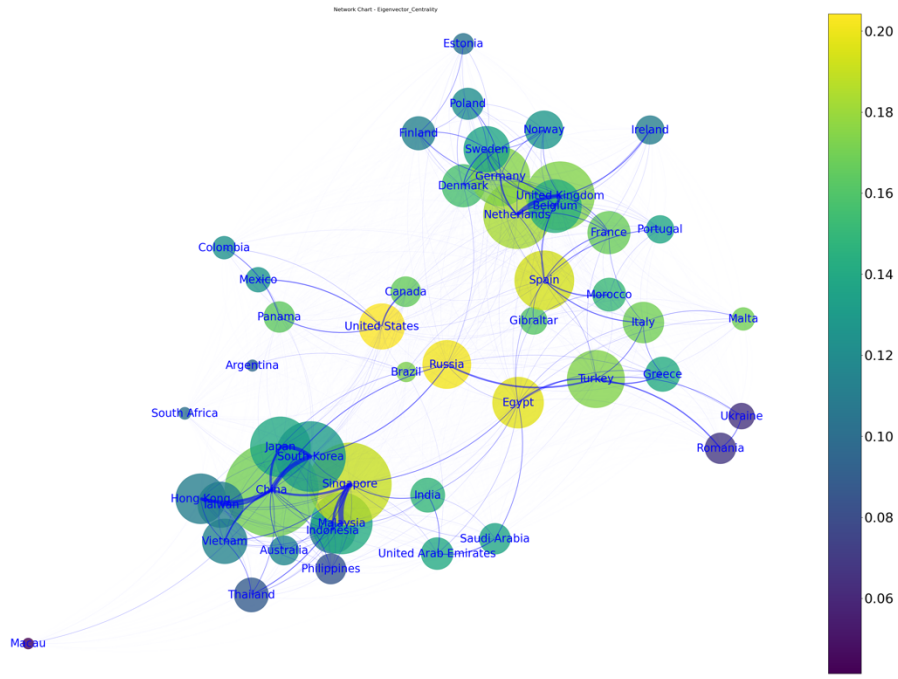
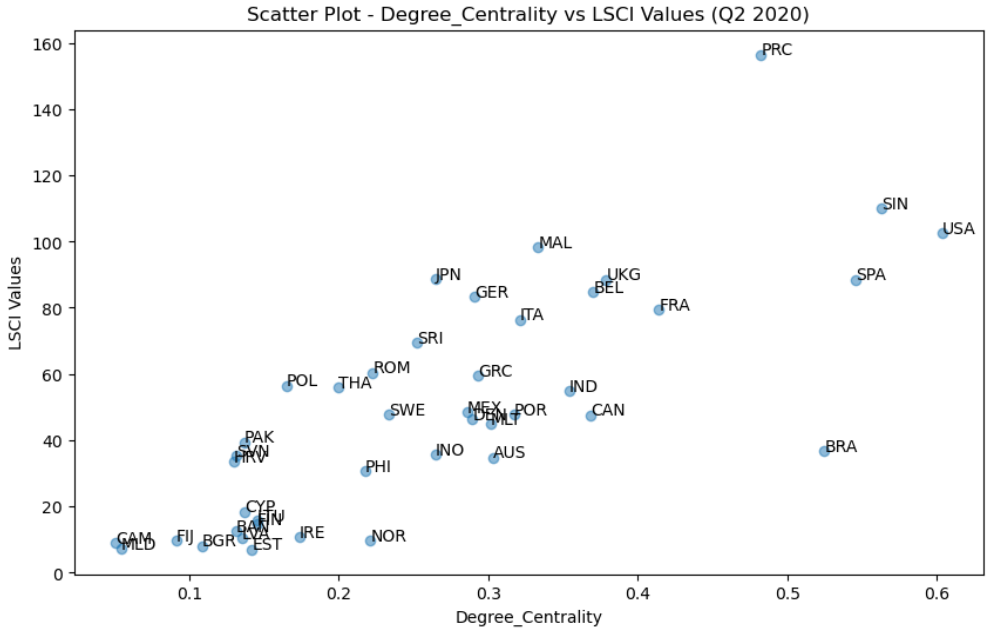


Fig 4.3. The generated network chart represents the trade relationships between countries, with node size indicating the total vessel movement and node color representing the Eigenvector Centrality

Applications, relation of Centrality Measures with other Indicators:

1. Relation of Degree Centralities of Countries with Liner Shipping Connectivity Index:

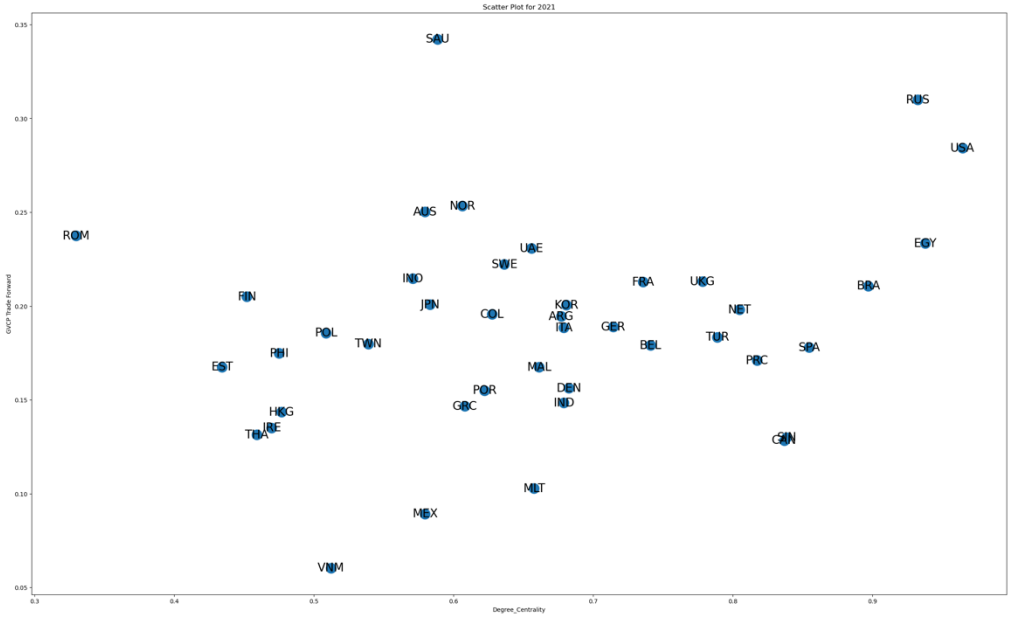
The Liner Shipping Connectivity Index (LSCI) is a measure that assesses the connectivity of a country's maritime shipping network. It quantifies a country's integration into global container shipping routes by considering factors such as the number of shipping services, the size of vessels, and the frequency of port calls.
Degree centralities derived from network analysis show a highly correlated relationship with the Liner Shipping Connectivity Index.



This strong correlation suggests that countries with higher degree centrality are more extensively connected in terms of liner shipping routes, indicating their enhanced accessibility and integration into global maritime trade networks. he scatter plot shows the relationship between the Liner Shipping Connectivity Index (LSCI) and the degree centrality of the top trading countries. The LSCI is a measure of a country's maritime connectivity, and it is calculated based on factors such as the number of shipping lines serving a country, the size of the largest vessel used on these services, and the number of services connecting a country to other countries. The degree centrality is a measure of a country's importance in the global trade network, and it is calculated based on the number of direct trading partners a country has.
The scatter plot shows that there is a positive correlation between the LSCI and the degree centrality. This means that countries with a high LSCI tend to have a high degree centrality, and vice versa. This is because countries with a high LSCI are more likely to be involved in global trade, and they are therefore more likely to have a large number of direct trading partners.
There are a few countries that stand out on the scatter plot. China has the highest LSCI, and it also has a high degree centrality. This is because China is a major trading hub, and it is involved in the production and exchange of a wide range of goods and services. Singapore also has a high LSCI and a high degree centrality. Singapore is a global financial center, and it is a major transhipment hub for container shipping.
There are also a few countries that have a low LSCI but a high degree centrality. Nigeria and Brazil are two examples of countries with this profile. These countries are major exporters of commodities, and they are therefore involved in a lot of trade with other countries. However, their LSCIs are relatively low, because they do not have as many shipping lines serving their ports or as many services connecting them to other countries.

2. Relation of Centrality Measures with Global Value Chain Participation of the Economies:

The GVCP is a measure of a country's involvement in global value chains, and it is calculated based on the share of a country's exports that are intermediate goods. The degree centrality is a measure of a country's importance in the global trade network, and it is calculated based on the number of direct trading partners a country has. Degree centralities obtained from network analysis exhibit a weak correlation, with correlation coefficient being ~0.2 with the Global Value Chain forward participation ratio. This suggests that there are other factors that affect a country's GVCP forward and degree centrality,
The scatter plot shows the GVCP for forward linkages. This means that it measures the extent to which a country is involved in the production of intermediate goods that are used in the production of final goods.



Interestingly, the plot highlights United Arab Emirates has a high GVCP forward but a low degree centrality:
Possibly because United Arab Emirates is a major producer of oil and gas, which are intermediate goods that are used in the production of a wide range of final goods. SAU is a major hub for the transit of goods, which means that it does not necessarily need to have a large number of direct trading partners in order to be involved in global trade.

Russia and the United States are both major players in global value chains. They have high GVCPs and high degree centralities, which means that they are both involved in the production and exchange of a wide range of goods and services. Russia is a major producer of oil and gas, which are intermediate goods that are used in the production of a wide range of final goods. Russia is also a major exporter of commodities, such as metals and minerals. This means that Russia is well-positioned to participate in global value chains.
The United States is a major producer of both intermediate and final goods. The United States is also a major importer of goods and services, which means that it is well-connected to other countries in the global trade network. This makes the United States a major player in global value chains.

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