ASSESSING THE IMPORTANCE OF ASIAN PORTS BY APPLYING SOCIAL NETWORK ANALYSIS

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Abstract
The paper aims to analyze the characteristics of the containerized maritime routes between 153 ports. For this purpose, a network analysis was conducted. A particular attention has been paid to the 78 major Asian ports in the sample, 36 out of which are among the ASEAN designated container ports. We have created three networks. The first two are related to the maritime network between the ports at a port and at a country level, while the third one is an Asian trade export network at a country level. The study shows that among the 10 highest ranked ports based on degree, betweenness and closeness centralities, eight are from Asia. This indicates a high risk of congestion which is confirmed by the high bottleneck scores of the Asian ports. In the maritime network, we have identified a cluster composed of 34 countries from all regions, which means that the countries' trade interactions are no longer defined by the geographical position of their ports. The maritime network of Asian countries has a scale-free structure with a relatively high density whereas the Asian trade network is characterized by a clique structure. Finally, the regional integration was found to be stronger within the trade country network, this is especially true for ASEAN+3 states.

Keywords: Network theory, Asian ports, ASEAN states, trade network, maritime port network

Introduction
According to the International Maritime Organization, over 90% of the world's trade is carried out by sea. It is the cheapest and most efficient way to transport goods in big quantities. Considering the fact that different commodities are transported by different types of ships and given that each commodity has its own specifications in terms of weight and price, the shipping industry should be analyzed by taking into account the volume and also the value of the transported cargo (Kutin et al., 2015). Even though containerized cargo accounts for only 10% of the total volume, its value represents 52%. Since the 1960s, containerization has greatly reduced the expense of international trade and increased its speed. According to the data of Clarkson Research, since 1990, the containerized trade has increased by more than 600%. It has also dramatically changed the character of ports' infrastructure. Moreover, the role of China in the containerized industry has become very important. In 2016, more than 20% of containerized seaborne trade was passing through the Chinese ports.

However, the industry is still facing high level of vulnerability. Following the Subprime crisis, in 2009 container prices fell by 14% (UNCTAD, 2009). Since then, the industry has been in an unstable state. UNCTAD highlighted the mismatch between supply and demand in the containerized trade. The growing imbalance of the trade South-Nord forced liner shipping companies to work together in order to reduce their operating costs. These strategies have an effect on the container terminals development. Confronted by the growing size of the ships and the continuous increase in the containerized goods, the ports have to find the most suitable solution to adapt to these trends. The immediate challenge for ports is to adapt to these increased volumes of containers throughput and the size of the ships. (Notteboom, 2010) stated that *"the success of the port is strongly affected by the ability of the port community to fully exploit synergies with other transport nodes."* Therefore, a suitable method to measure the connectivity of container ports is Social Network analysis. Such an analysis is a good complement to traditional measures of individual throughput Ducruet et al. (2010).

ASEAN member states have become more integrated in the world economy, but also, they have increased the trade between them by launching the ASEAN Economic Community in 2015. According to (Tongzon and Lee, 2015) this integration will result in lower shipping cost and improved quality of shipping throughout the region, and thus contribute to an improvement in the ASEAN members' trade performance and international competiveness. Therefore, the position of the ASEAN community in the maritime and global trade networks needs to be analyzed.

Our research aims to determine the characteristics of the maritime and the trade networks at a port and country levels by using graph theory. We analyze the characteristics of the maritime routes between 153 major container ports in the world. A particular attention is paid to a subset of 78 Asian ports. The study aims to respond to the following questions:

- ***What are the characteristics of the maritime port network and the trade network?***
- ***What is the effect of the container throughput on the country's main centrality indicators?***
- ***What are the main differences between the maritime and the trade networks in the Asian and ASEAN regions?***

The remainders of this paper are as follows. Section 2 discusses the literature related to Network Analysis in maritime economics. Section 3 explains the methodology and the data used. All the results are depicted in Section 4. Finally, a discussion on the outcomes of the study and possible future research are provided in section 5.

Review of the literature

In the last decade the network theory has gained a considerable importance in the maritime logistics. The cost effectiveness and production efficiency of ports are closely linked to the optimization of their networks. (John et al., 2016) applied Bayesian belief networks to model various influencing variables related to different risk' factors in a seaport system. They have provided useful recommendation to policy makers to optimize the operations of their systems for resiliency. (Peng et al., 2016) used a mixed-integer nonlinear stochastic programming model and showed that the deployment of the containers handled at each seaport is not directly related to its throughput capacity.

Notteboom (2010) conducted a detailed container traffic analysis for the period 1985–2008 for 78 ports. His study shows that European ports function not as individual places that handle ships but within supply chains and networks. There is also a gradual deconcentration process and the container handling market remains more concentrated than other cargo handling segments. The author also suggests that the container port hierarchy and competition in Europe have become highly complex and dynamic due to structural changes in logistical, economic, institutional and regulatory settings.

Ducruet (2013) applied network simplification techniques based on the linkage analysis, which consist in removing from each port all its links except the largest one. Their study revealed that the most diversified ports have a high level of centrality and dominance in the network. They also connect with more ports situated on a greater physical distance. On the other hand, the more specialized ports concentrate the majority of global traffics, but their average connection distance is lower due to their distribution role at the intra-regional level.

Network analysis on international trade flows has been widely done in the economic literature (Snyder and Kick, 1979), (Smith-White and Preiss, 1992), (Kim and Shin, 2002), (De Benedictis and Tajoli, 2011)). The trade flow of goods and services between countries can be presented by directed graphs where all edges are potentially bidirected, as long as exports and imports between two countries are nonzero values. We can perform the same analysis on the Maritime Routes Network. By looking at the trade flows as a network, allows analyzing either the relationship between the countries in the network or the overall network structure. A recent analysis to both trade and FDI flows within ASEAN+3 has been conducted by (Nguyen et al., 2017). They conclude that, first, the degree of trade and FDI integration varies among ASEAN+3 member states over the 1990-2012 period. Second, ASEAN+3's intra-regional trade network seems to be more densely connected than its intra-regional FDI network. Third, large and/or advanced countries tend to be better linked and form a sub-regional bloc of tightly connected economies. Regarding the efficiency of ASEAN ports, (Kutin et al., 2017) found that most of the ASEAN container ports operate under increasing returns of scale, which means that they are able to handle even more containers. (Banomyong, 2015) applied Geographical Simulation Model (GSM) to analyze the effects of the implementation of The Master Plan on ASEAN Connectivity (MPAC) by the members' states. The study shows that the development is mostly concentrated in specific locations and countries with better trade facilitation. The positive effect could spread to non-ASEAN member states such as Japan, China and India, countries with better trade facilitation environment.

A major gap in the literature review is the lack of any research about the maritime trade routes at a country and at a port level using Social Network Analysis. Moreover we were not able to find many studies related to the effect of the maritime connectivity on the overall trade performance of a country. Hence, our study aims at fulfilling these gaps and providing useful recommendation to policy makers to optimize their network and to implement their mid and long run trade policies based on trade connectivity.

Methodology and data

Social network analysis (SNA) is the process of investigating social structures through the use of networks and graph theory (Otte and Rousseau, 2002). A network, as in Figure 1, is a collection of nodes, and links (or edges) between nodes. In our case, the nodes are either a port or a country, and the link can be the flow of exports from one country to another country, or any maritime/ports indicators, as the average containerships size between the two ports. The importance of the flow depends on the link weight. Since, there is always one source of the flows, and one target, e.g. a ship that moves from one port to another port, our network is directed.

Figure 1: Example of a simple directed network between 3 countries.

Social Network Analysis in the context of maritime trade

To gain a better understanding of the connectivity in the Maritime network, and with respect to the network literature ((Freeman, 1978), (Newman, 2001), (Borgatti, 2005)), a broad set of well-known centrality measures was used. The centrality approach, which is based on the number of maritime links of a given port and their strength (number of ships or TEUS), assesses how well connected a port is to the rest of the network and how influential a port is, for example within a specific region (see Figure 2). According to (Jackson, 2010), centrality measures can be classified into four main groups: i) degree centrality - assessing how a node is connected to others, ii) closeness centrality - showing how easily a node can be reached by other nodes, iii) betweenness centrality - describing how important a node is in terms of connecting other nodes, and iv) eigenvector centrality measure (or the Bonacich centrality) - referring to how important, central, influential, and tightly clustered a node's neighbours are.

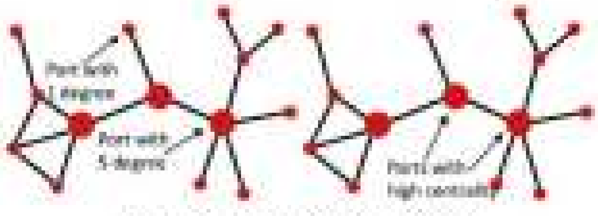

Figure 2: Degree and centrality.
Source: (Freire Seoane et al., 2013)

A related question of interest is to know if one port belongs to a particular community of ports, and, if yes, how is this community defined? As suggested in (Pons, 2005) and (Pons and Latapy, 2006), the concept of community within graph theory is not clearly defined. However, it is possible to define a community as a set of vertices (links) whose density of internal connections is greater than the density of connections to the outside (Pons, 2005). Accordingly, to calculate the potential communities within a given network, one should split the network into a given number of groups. Among others, agglomerative algorithms are the most well-known ones.

One of the aims of this article is to detect the structure/configuration of the network. Among the different types of network, the two more frequently used ones in maritime and trade literature are the Hub and Spoke networks (Figure 3). The first one is a system of connections, where all traffic moves along spokes connected to the hub at the center. In the maritime network a typical example of a hub-port is the Port of Singapore. We could also have multi-port calling configuration where the vessel is delivering goods to many ports. Such a system is used by smaller containerships.

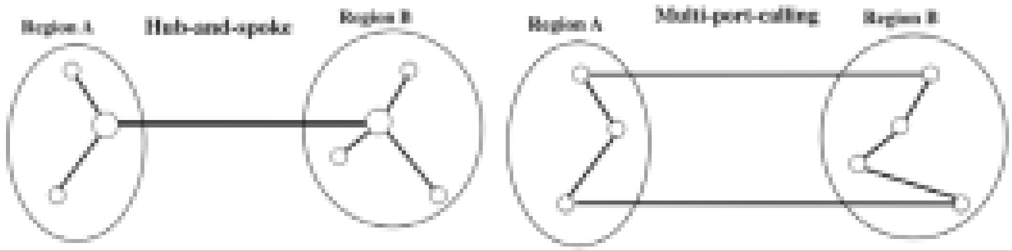

Figure 3: Hub and Spoke versus Multi-Port Calling configuration.
Source: (Imai et al., 2009)

Imai et al. (2009) found that in most scenarios the multi-port calling is superior in terms of total cost, while the hub-and-spoke structure is more advantageous in the European trade for a costly shipping company.

Data
Our maritime database was obtained from Lloyd's Marine Intelligence Unit (LMIU) and contains information about port to port transport in 2014. It consists of 153 ports from 51 countries with 79 located in Asia, 27 in North America, 20 in Europe, 19 in Africa and 8 in the Latin America and the Caribbean. The following variables are in the dataset:

- Container port of departure (A)
- Container port of arrival (B)
- Average size of the ships in dead weight tonnage (DWT) going from port A to port B
- Average size of the ships in Twenty-Foot Equivalent Unit going from port A to port B
- Number of ships going from port A to port B
- Number of operators transporting goods from port A to port B
- Number of trips between from port A to port B

The export database was collected from UN ComTrade [1] commodity databases in the Standard International Trade Classification (SITC) Revision 3.

We have built three types of network. The first one is the trade network which takes into account all exported goods between the countries in the sample and gives the value of exports in thousands of dollars. The second one is "maritime network" which includes the ports in the sample. We also have a third network which is the maritime network at country level. It should be emphasized that the dataset neither includes all the operational ports in each country nor has data for all countries in the world.

Results
The network analysis was conducted by using the following softwares: Gephi and Cytoscape (version 3.5.0.). The first sub-section presents the results at port level while in the second one depicts the outcomes of the research at country level. The last two parts show the effect of the container throughput on the ports main centrality measures and the trade and maritime networks of Asian and ASEAN states.

[1] https://comtrade.un.org/

Container Ports' network
At the port level, weights have been attributed to the nodes and links according to the average size or the dead weight tonnage[2] of the containerships that operate on a given route or that dock at a particular port as well as the average number of operators or trips between any directly connected ports/countries (Appendix 1, Table A1). The descriptive statistics of the nodes and link attributes shown in Appendix 1, Figure A1 depict a significant dispersion around the mean as the studied sample consists of highly heterogeneous ports and maritime routes. Table 1 shows that the network has a high degree of connectivity. On average, the distance between any two connected nodes is 1.809 edges and each of them interacts with approximately 48 other ports in the sample.

Clustering Coefficient	0.690409154
Connected Components	1
Diameter	4
Radius	2
Connected Pairs/Shortest Paths	23256
Average Short Path Length	1.808565531
Average Neighbors	47.81699346
Node Count	153
Number of edges (without self-loops)	6410
Density	0.2756

Table 1: Network Statistics – Port level data

The clustering coefficient of the global network reflects the average neighbourhood connectivity. It is relatively significant (0.69) as it should be expected considering the average number of neighbours of each node. Therefore, there is a possibility that many cliques[3] and communities exist within the maritime network. It is observed that the network density is small. These results indicate that the network has a scale-free configuration. Such networks, introduced by (Barabási and Albert, 1999) are mainly characterized by a degree distribution that follows a power law with a few highly connected nodes and a majority of low-degree nodes.

The port ranking based on centrality measures (Appendix 2, Table A2) indicates that Asian ports have become major focal points in the maritime sector. Among the 10 highest ranked ports based on degree, betweenness and closeness centralities, eight are from Asia. The absence of North American ports in that ranking surely contrasts with the port hierarchy that existed around two decades ago. This can be explained by the on-going industrial relocation process of North American firms to Asia (particularly in China and ASEAN member states).

Port rankings according to different centrality measures are very similar due to the positive correlation between degree, betweenness and closeness centralities (Appendix 2, Figure A2). This indicates a high risk of congestion which is common in scale-free networks and can affect the network resiliency. Therefore, the coefficient of bottleneck score for each node was computed. Not surprisingly, ports that capture a large portion of containerized traffic also have high bottleneck scores, i.e. Shanghai, Antwerp or Ningbo-Zhoushan (Appendix 3, Figure A3). This topological measure is also an indicator of the lack of "redundancy" in any given network as any dysfunction or removal of one of those hubs can lead to the separation of different clusters or communities. This can lead to the destabilization of the logistics chain (Xu et al., 2015)

Maritime network at country level
Given that dataset include main ports from different countries, the data has been aggregated to a country level in order to analyze the countries' interactions. This section focuses on two aspects of the containerized trade between countries. Firstly, we consider the vessel movements between each pair of countries similarly to the port network analysis. Secondly, we analyze the trade patterns between them. The objective is to identify the differences between the two maritime networks at port and country level.

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[2] Ship sizes and dead weight tonnage are expressed in twenty-foot equivalent unit (***TEU***).
[3] A small close-knit group of people who do not readily allow others to join them.

The maritime Network at country level

At country level, the maritime network is a polarized or scale-free structure with a high level of connectivity. It is a core-periphery structure where the most important countries are the world's main importers and exporters. Countries such as China and USA are the most connected nodes while most countries have a relatively low connectivity according to degree centrality (Appendix 4, Figure A4.1). Thus, it is the level of economic activities in each region that defines the spatial disparities within the maritime network. The hubs identification confirms that the regions that host the most important ports are located in North America, Western Europe and East Asia (Appendix 4, Figure A4.2).

When detecting highly dense sub-networks, two clusters have been identified (Appendix 4, Table A4.1). However, the focus has been put on the first cluster which is composed of 34 countries from all regions. This is a proof that within the considered cluster and to a lesser extent, the entire global network, the countries' trade interactions are no longer defined by the geographical position of the ports as mentioned by (Ducruet et al., 2010). Although trade network and the maritime network are structurally different, the international trade patterns can still be observed in the whole maritime network and they are even more visible when studying its main cluster of countries.

Comparison of the Maritime Routes' and Country level Trade's Networks

Table 2 shows that the trade network has a higher level of connectivity than its maritime counterpart. Its clustering coefficient is close to 1 and it has smaller characteristic path lengths, which is very close to the characteristics of a clique.

Maritime Network - Country level		**Trade Network - Country level**	
Clustering Coefficient	*0.79418764*	*Clustering Coefficient*	*0.978*
Connected Components	*1*	*Connected Components*	*1*
Diameter	*3*	*Diameter*	*2*
Radius	*2*	*Radius*	*1*
Connected Pairs/Shortest Paths	*2550*	*Connected Pairs/Shortest Paths*	*2550*
Average Short Path Length	*1.40470588*	*Average Short Path Length*	*1.024*
Average Neighbors	*32.4313725*	*Average Neighbors*	*49.808*
Node Count	*51*	*Node Count*	*51*
Number of edges (without self-loops)	*5650*	*Number of edges (without self-loops)*	*2490*

Table 2 – Regression results, maritime network at country level

As stated in the previous section, countries are strongly connected in terms of trade of goods. On the other hand, they are less clustered when analysing the containership traffic between their main ports. In the last two decades, the international trade has had on average an annual growth rate doubling the world's production, particularly due to the integration of the emerging countries in international trade (BRICS and most of the ASEAN member states).

There are some fundamental differences between maritime and trade networks. For instance, the likelihood of two countries becoming trade partners is mainly based on *incentive-based market mechanisms and potential comparative advantages*. On the other hand, the maritime sector is mainly guided by the carriers' incentives to optimize their costs and profits. However, both networks have a fair share of drawbacks. While the trade network is not optimal for ship operators in terms of efficiency, the maritime network is confronted by the risk of empty cores which are issues that arise when there is a lack of competitive equilibrium and an inefficient use of resources due to high sunk costs, inelastic demand and excess capacity etc., (Button and Nijkamp, 1998).

How does container throughput affect ports main centrality measurements?

In order to analyze the correlation between the degree centrality of country in the maritime network and its container port throughput as well as the level of its neighbourhood connectivity, an estimation using the OLS method was performed in the following form:

$$Log\ (Degree) = \beta_0 + \beta_1 * Neighborhood\_Connectivity + \beta_2 * Container\ Port\ Throughput + \varepsilon$$

As displayed in the results in Table A5 (Appendix 5), when a country has highly connected neighbours, it decreases its number of interactions whereas its container port throughput per country increases its degree centrality. Collecting cargo from their point of origin and transporting them to the hub so that the shipment can be distributed to its destination ensure the optimization of the capacity use of containerships.

Moreover, these past decades have seen a rise in public-private partnerships to invest in port infrastructures. Major operators have been taking an important part in making sure that they do not only position their terminals in strategically placed ports but they also ensure that such hubs are fully equipped because they are the main areas for transhipments. Their closeness centrality implies that they can manage the operations with the peripheral ports, while betweenness centrality entails that they are the swivel plates that connect different regions which are tightly connected in the trade network. This confirms that the maritime and the trade network have different topological structures whilst the maritime flows are in fact a reflection of trade relations between countries.

Asian countries, comparison between Trade and Maritime Networks at a country level

Since the dataset includes all major ports in Asia, we focus our analysis to the particular case of the maritime and trade sub-networks defined only by either all the Asian Countries, or by the ASEAN member states. At first glance, it is observed that major economies which serve as bridges toward Europe and North America play a substantial part in the interactions at a regional level, in both networks.

Obviously, the global statistics for both networks show a different configuration for each of them (appendix 6, Table A6). The maritime networks for both Asia (ASEAN included) and the ASEAN community show a scale-free structure with a relatively high density where most countries are clustered except for Brunei, Cambodia and Turkey as such countries either play a small role in the network or do not maintain interactions that go beyond their geographical surrounding.

On the other hand, both the trade networks for Asia and ASEAN are characterized by a clique structure. They have shorter distances and the density as well as the clustering coefficient are equal to 1, which means that all the possible interactions between countries are achieved.

Moreover, it was deemed necessary to compare the level of integration between the maritime and the trade network (Figure 3).The links in the Asian maritime network are weighted by the number of operators whereas in the trade network, they are weighted by the value of exports in thousands of USD.

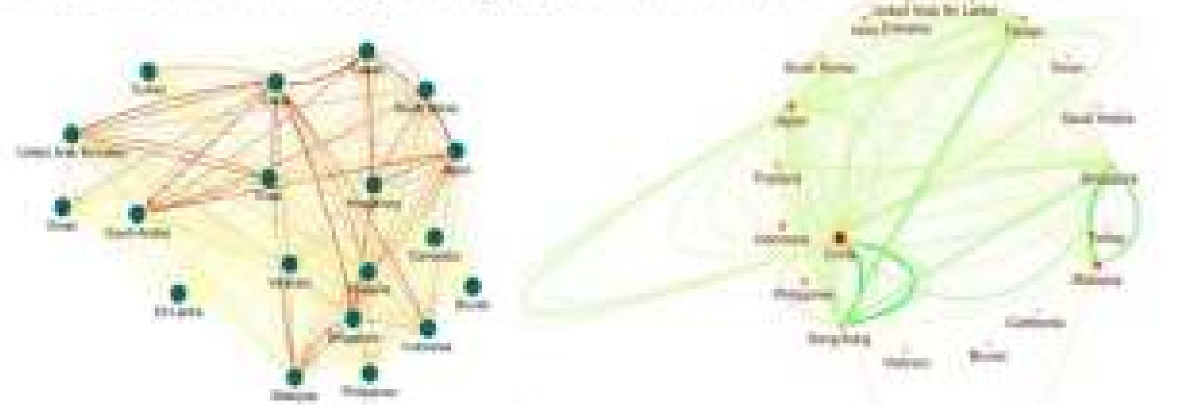

Figure 3: ASIAN Cluster in the Trade network (left) and the Maritime network (right)

The trade network shows a higher level of integration though similar linkage patterns can be observed in both the trade and the maritime networks. Countries such as China, Singapore and Japan have stronger trade linkages and also a high level of competition among them. These countries have a high level of GDP, which indicates the positive relationship between maritime connectivity and economic growth.

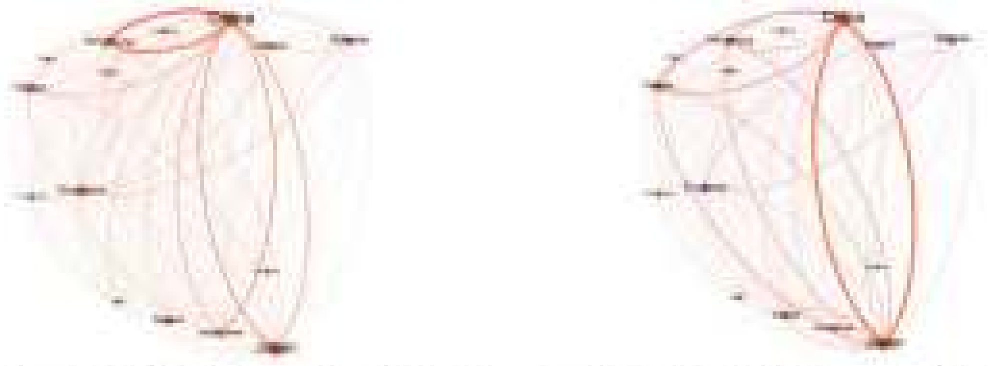

Figure 4 - ASIAN Communities in the Trade network (left) and the Maritime network (right)

We also analyze how the regional integration is reflected within the network of Asian countries. As shown in Figure 3 and 4, the regional integration is stronger within the trade network. When we consider the communities of all the countries belonging to ASEAN+3, except Cambodia belong to the same community. On the other hand, the Maritime network (right hand side, Figure 4) is defined by the link between China and Japan. There is also another community which includes Singapore, Malaysia, Indonesia, Cambodia and Brunei.

Conclusion

This study aims at understanding the characteristics of the maritime and the trade networks using graph theory and analysing the differences between them, either from a global perspective or within the Asian and ASEAN regions. It also studied the factors influencing a country's degree centrality. Our findings show that the maritime network is characterized by a core-periphery structure associated with scale-free networks and is guided by shipping carriers cost minimization incentives whereas the trade network which is a small-world structure reflects the ongoing globalization process and regional integration. This explains why the linkages have been found to be stronger within the trade network than in the maritime network.

Regarding port classification based on degree, betweenness and closeness centralities, it is observed that Asian ports are the most connected, while North American ones have significantly lower scores. It suggests that some trends in the maritime sector such as trade liberalization, outsourcing and technological progress have had a major impact on the countries' connectivity. However, high bottleneck score of Asian ports indicates a high level of congestions and potential negative effects on the global supply chain, in case of removal or dysfunction of one of the Asian hub ports. The ports with high level of container throughput also have a high degree centrality. This confirms that the maritime network is a hub and spoke. Such structure can be characterised by a low level of resilience. This characteristic can be explained by the rise of in public-private partnerships to invest in port infrastructures and the increase of the size of containerships and the strategies of liner shipping companies to realize economies of scale.
When analysing the maritime network at a country level, we found that main exporting countries such as China and USA are the most connected nodes while the majority of states have low degree centralities. It suggests that it is the level of economic activities in each region that defines the spatial disparities within the maritime network. The identification of a cluster of 34 states from different continents show that trade interactions between the states are no longer defined by their geographical positions. In the case of trade network, we found that the countries' centralities measures are higher than their scores in the maritime network. Another important finding is the fact that states with very well connected neighbours have less interactions (number of containerships operating between the two countries).

The analysis on the trade network of Asian and ASEAN states show that countries such as China, Singapore and Japan have stronger trade linkage. All ASEAN +3 states except Cambodia have very strong trade relations. On the other hand, the maritime network at a port level reveals a strong link between China and Japan. Another cluster of mutually connected countries is composed by Singapore, Malaysia, Indonesia, Cambodia and Brunei. This suggest that additional efforts should be undertaken to integrate Cambodia in the ASEAN Economic Community. In order to improve the implementation of the ASEAN Single Shipping Market we should further analyze why in the maritime network, the cluster of countries does not include Thailand, Vietnam and Philippines.

On the basis of our results, further research to link empirical facts (links in the network) with the optimal possible routes given by an operational research optimization would allow to deepen the analysis of the shipping carriers' strategies on maritime routes while testing the efficiency of the global port network.

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<u>Appendices:</u>

Appendix 1: Container Port' network

Nodes attributes						
Attribute	***Min.***	***1st Qu.***	***Median***	***Mean***	***3rd Qu***	***Max.***
Total TEU of arrived vessels at each port	0	581824	1351088	2633576	2969636	16303330
Total TEU of departed vessels at each port	0	474527	1219443	3194332	3653856	25770455
Links attributes						
Attribute	***Min.***	***1st Qu.***	***Median***	***Mean***	***3rd Qu***	***Max.***
Avg.TEU	80	1712	4082	4300	5867	18270
Avg.Dwt	2351	24278	51542	54885	73906	194335
No.of.Ships	1	2	9	25.2	27	1237
No.of.Trips	1	2	21	99.7	90	5510
Estimated TEU between ports	80	8412	57890	391881	361053	14386449
No.of.Operators	0	2	5	11.13	13	284

Table A1- Descriptive Statistics

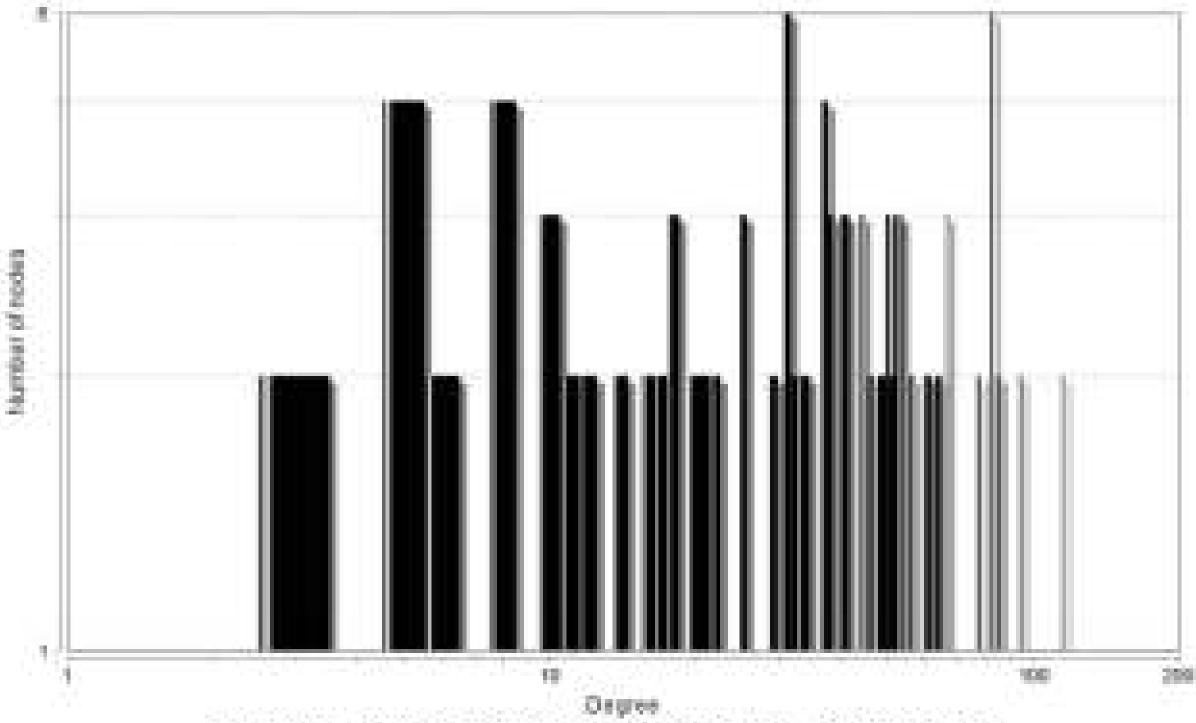

Figure A1- Degree distribution of maritime network - Port level data

Appendix 2: Port ranking based on centrality measures

	Top 20 in port network file ranked by the Degree method		Top 20 in port network file ranked by the Closeness method		Top 20 in port network file ranked by the Betweenness method	
Rank	Container Port	Score	Container Port	Score	Container Port	Score
1	Singapore	241	Singapore	138.50	Singapore	1873.04
2	Hong Kong	233	Shanghai	136.50	Shanghai	1257.84
3	Shanghai	229	Hong Kong	136	Hong Kong	1234.02
4	Ningbo-Zhoushan	219	Shenzhen	133.50	Ningbo-Zhoushan	790.04
5	Shenzhen	217	Ningbo-Zhoushan	133.50	Shenzhen	769.07
6	Port Klang	197	Port Klang	129	Port Klang	706.83
7	Kaohsiung	197	Kaohsiung	127.50	Kaohsiung	665.08
8	Rotterdam	188	Rotterdam	126.67	Antwerp	479.87
9	Antwerp	178	Port Said	126.50	Algeciras	477.63
10	Tanjung Pelepas	172	Antwerp	124.33	Rotterdam	404.35

Table A2 - Port ranking by degree, closeness and betweenness centralities – Port level data

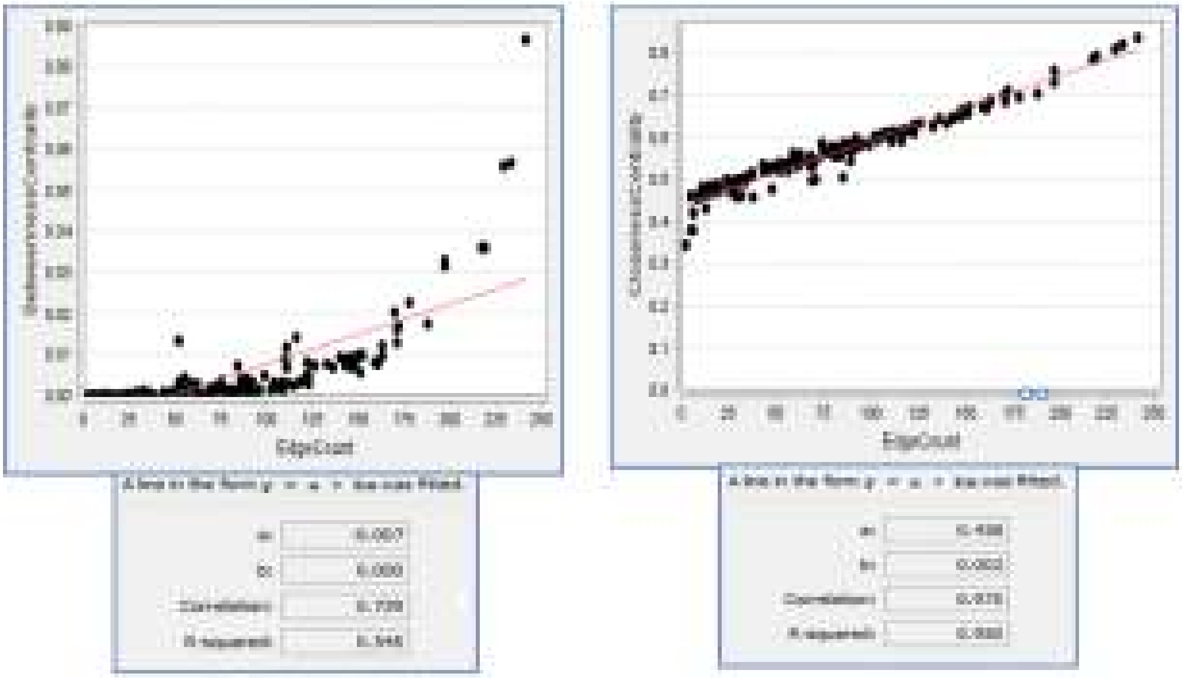

Figure A2- Correlation between degree centrality and closeness and betweenness centralities

Appendix 3: Bottleneck scores

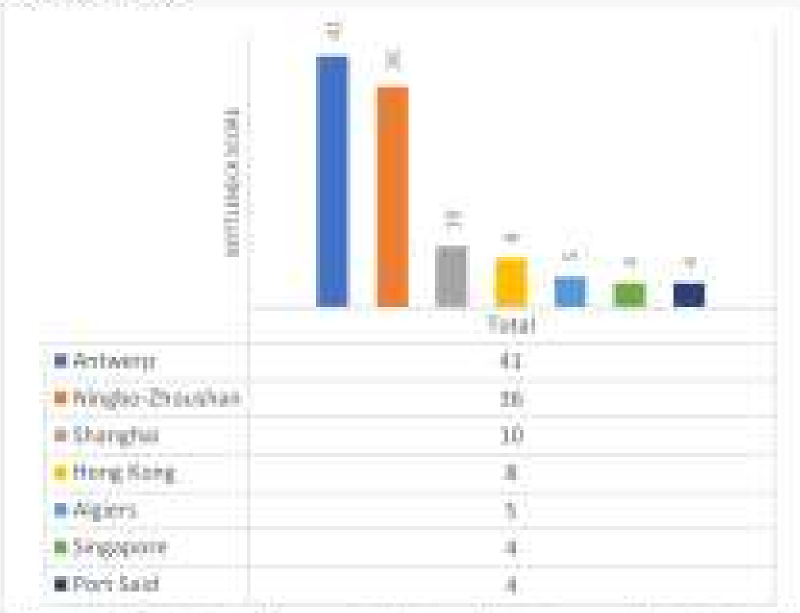

Figure A3: Ranking of the ports with the highest scores for bottleneck

Appendix 4 Maritime network at a country level

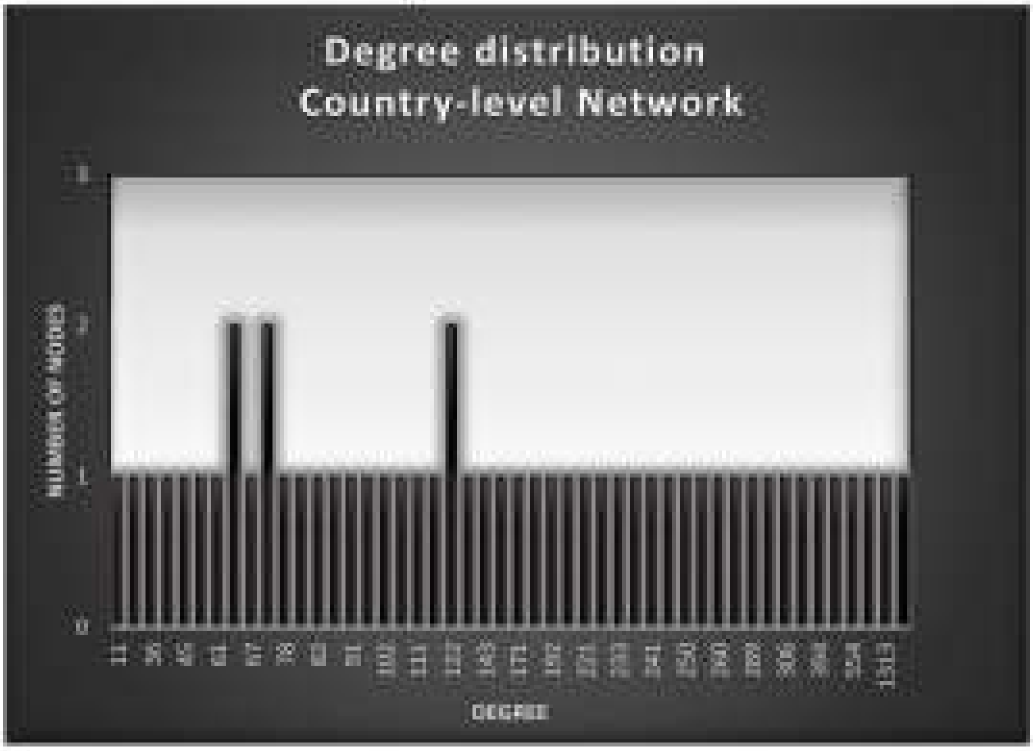

Figure A4.1: Degree distribution of maritime network – Country level data

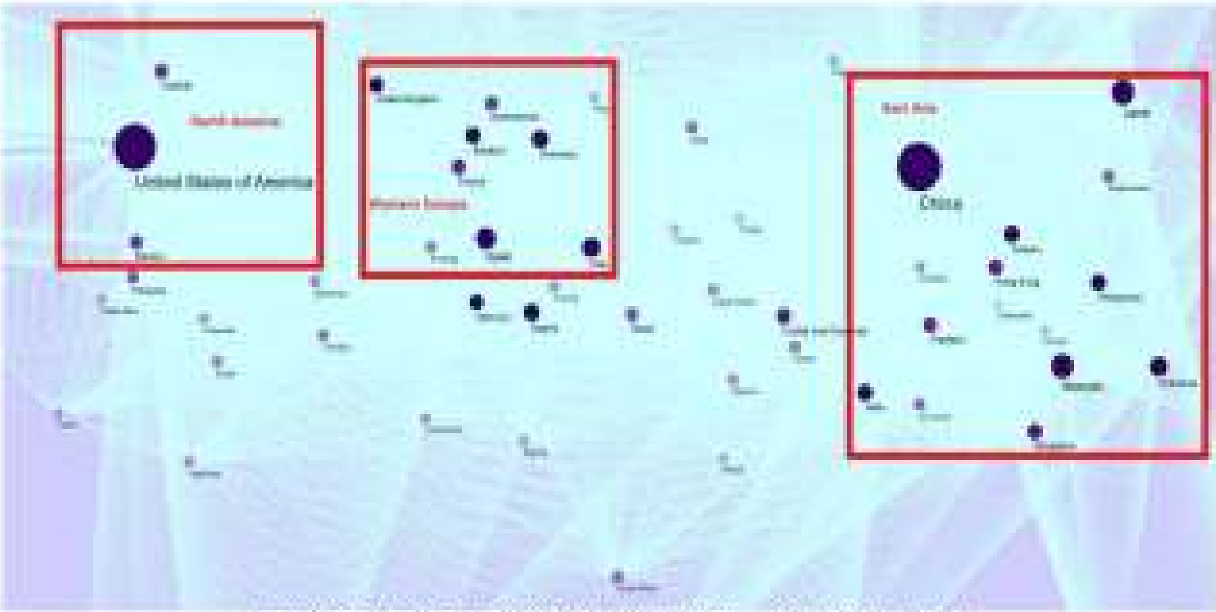

Figure A4.2: Maritime network visualisation – Country level data

Cluster	Score (Density*#Nodes)	Nodes	Edges	Node IDs
1	31.516	34	520	Brazil, Germany, Saudi Arabia, Malaysia, Argentina, Portugal, France, India, Egypt, China, Belgium, Djibouti, Algeria, United States of America, United Kingdom, United Arab Emirates, Taiwan, Sri Lanka , Spain, Singapore , South Korea , Panama, Oman, Netherlands, Morocco, Jamaica, Mexico, Malta, Bahamas, Thailand, Japan, Italy, Hong Kong , South Africa
2	3	7	9	Nigeria, Ivory Coast, Philippines, Indonesia, Russia, Costa Rica, Poland

Table A4.1 – Maritime network cluster – Country level data

Appendix 5: Container throughput and centrality measurements

```
lm(formula = log(Degree) ~ Neighborhood_Connectivity + CPT, data = DEGREE)
Residuals:
   Min      1Q    Median     3Q     Max
-1.9870 -0.1830  0.0232  0.2323  1.1741
Coefficients:
                            Estimate   Std. Error  t value  Pr(>|t|)
(Intercept)                 1.214e+01  1.424e+00   8.523   1.06e-10 ***
Neighborhood_Connectivity  -2.027e-01  3.681e-02  -5.507   2.03e-06 ***
CPT                         2.864e-08  1.402e-08   2.042     0.0475 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Residual standard error: 0.4964 on 42 degrees of freedom

Multiple R-squared:  0.5949,        Adjusted R-squared:  0.5756
F-statistic: 30.84 on 2 and 42 DF,  p-value: 5.745e-09
```

Table A5: Country level data –Maritime network global stats versus Trade network global stats (ASIAN & ASEAN regions)

Appendix 6: Asian Countries and maritime network

MARITIME NETWORK				
Network Stats - ASIA			**Network Stats - ASEAN**	
Clustering Coefficient	0.847987049		***Clustering Coefficient***	0.89642857 1
Connected Components	1		***Connected Components***	1
Diameter	3		***Diameter***	2
Radius	2		***Radius***	1
Connected Pairs/Shortest Paths	342		***Connected Pairs/Shortest Paths***	56
Average Short Path Length	1.257309942		***Average Short Path Length***	1.142857143
Average Neighbors	13.47368421		***Average Neighbors***	6
Node Count	19		***Node Count***	8
Network density	0.748538012		***Network density***	0.857142857
Number of edges (without self-loops)	1595		***Number of edges (without self-loops)***	272
TRADE NETWORK				
Network Stats - ASIA			**Network Stats - ASEAN**	
Clustering Coefficient	1		***Clustering Coefficient***	1

Connected Components	1		*Connected Components*	1
Diameter	1		*Diameter*	1
Radius	1		*Radius*	1
Connected Pairs/Shortest Paths	342		*Connected Pairs/Shortest Paths*	56
Average Short Path Length	1		*Average Short Path Length*	1
Average Neighbors	18		*Average Neighbors*	8
Node Count	19		*Node Count*	8
Network density	1		*Network density*	1
Number of edges (without self-loops)	341		*Number of edges (without self-loops)*	56

Table A6 – Country level data – Maritime network global stats versus Trade network global