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Structures of Port Connectivity, Competition, and Shipping Networks in Europe

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Introduction

transport carries 80% of the global A container port's centrality (sometimes also named as connectivity) level based on graph theory (Freeman (1979), Opsahl et al. (2010)) is an important measure for a port's strategic location within the container transport system, and an indicator of its ability to attract cargo traffic and shipping service. In our recently published study (Liu et al., 2022), we focused on 29 major European container ports that have direct liner services with China and evaluate their centrality based on their connections with China and connections within the intra-European networks. For that purpose, we collected 323 intra-European liner services with 241 European ports and 27 liner services between Greater China and Europe with 29 European ports and 12 Chinese ports in 2019.

Index measures

Based on previous research, we proposed centrality indices should essentially measure a container port's strategic position from three dimensions:

- how many ports are directly connected with it (degree centrality)
- how closely/quickly it is connected with other ports in the network (closeness centrality)
- how inevitable its position is within the network (betweenness centrality)

Also, we design our indices to be service based, so that the commonly accepted critical factors for a port's connectivity level are considered, including the number of services, service capacity, service frequency, number of connected ports through direct services, and connection time. Therefore, service-based degree centrality for a port is defined as the number of nodes that it can reach directly within the service network without transfer. Service-based closeness centrality is measured as the total shortest transit time a particular port connects with all other ports within the network via liner services weighted by the connection capacity. The shortest path tree was calculated for each port using the Floyd Warshall algorithm (Floyd, 1962) to obtain the quickest transit time between each port pair. Finally, service-based betweenness centrality is measured as how often a particular port is located within the liner services in the network, weighted by the service capacity.

Key Findings

For each of the 29 ports, the three indices were calculated separately for the intra-Europe network (IEN) and China-connection network (CCN). The two networks show different patterns for the port centrality measures (Figures 1 and 2).

The three largest European ports (the 'first-tier' ports)

The largest three European container ports are the most "centrally" positioned for CCN network (a transoceanic network) with both connection speed, connection capacity, and number of direct connections. In the IEN network, the largest ports have slower connections in comparison to their smaller peers, but they compensate for this shortcoming with higher connection volumes. Within the largest ports, the major port function (transshipment vs. hinterland) and relationship with China influence centrality scores. For example, Hamburg always ranked after Rotterdam and before Antwerp in the CCN, despite its throughput being smaller than that of Antwerp. Hamburg port has almost one-third of its throughput from/to China (Hamburg Port Authority, 2012) clearly indicates that its strong relationship with China has led to relatively higher rankings than its peers (i.e., Antwerp). As in the IEN, Hamburg as a major gateway (vs. a transfer hub) for direct inland markets has low ranking especially low in betweenness and degree, and even lower when capacity was considered, suggesting that it did not connect intensively with other European ports and was often not included in intra-European services.

Piraeus

However, the most interesting finding is the high and clearly outlined scores of the port of Piraeus. Although Piraeus had the fourth largest throughput value among European ports in 2019, handled only a bit more than half of the throughputs of Hamburg and much fewer than Rotterdam and Antwerp. Despite its much smaller handling capacity and cargo throughput than the first-tier ports), Piraeus had a position almost as "central" as them in the service network with China. It had the quickest direct connection with China, both with and without capacity considered. In the IEN network, Piraeus outperformed all the other major and secondary ports with or without capacity considerations. For example, its betweenness ranked the highest with or without capacity, meaning that it is the most frequently included in existing services in the network. However, in comparison, its degree and betweenness measures in CCN are relatively weak, or should be considered as 'normal', ranking below the first-tier ports just as expected. Especially, its betweenness is ranked fourth with or without capacity measures, indicating that compared to the first-tier ports, it is less frequently included in existing services connecting China with Europe.

The findings of this research have important implications for shipowners, charterers, bunker traders, investors, and regulators. Specifically, the dynamic volatility spillovers among bunker markets are associated with the fluctuations in other bunker markets. The time-variant interdependence across different markets also influences significantly aggregate risk exposures for bunker markets. Put it differently, the risk exposures for bunker market source from the other bunker markets, freight

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markets and bunker futures markets. Considering the spillover effects from various markets volatility, market participants could have a more comprehensive understanding of risk dissemination across markets and improve risk hedging accordingly. In addition, the Singapore market acts as a leading bunker market to transmit volatility to other bunker markets and Singapore futures market. Therefore, traders could utilize the fluctuations in Singapore market to foresee the volatilities in other bunker markets, shipping freight markets, and bunker futures markets. Also, the research is helpful to improve the predicted ability of the volatilities among bunker markets, freight markets and futures market. Risk hedgers could improve their portfolios to be more efficient according to aggregate risk exposure. For policymakers, they could monitor the fluctuations in the Singapore market against potential risks to stabilize local markets.

Remark

The full manuscript of this abridged version can be accessed at Xiao-Xia Li and Tsz Leung Yip (2022). Dynamic interdependence and volatility spillovers across bunker fuel markets and shipping freight markets. Maritime Policy and Management.

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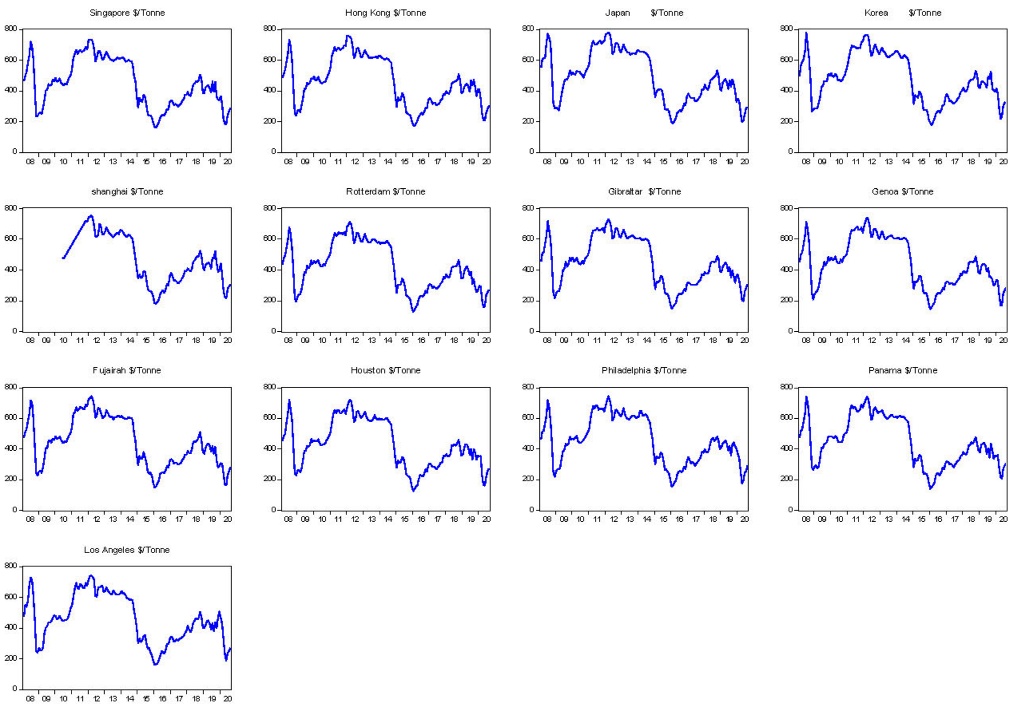
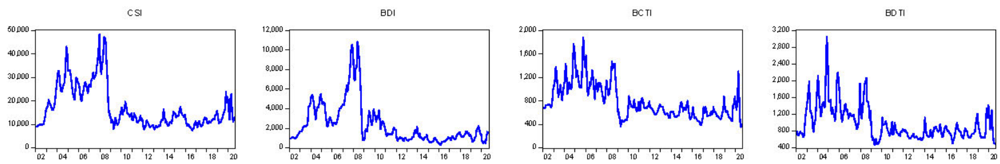
Figure 1. Figure (a) shows the monthly path of bunker prices in 13 ports, Figure (b) shows the indices of shipping freight rates, and Figure (c) shows the Singapore bunker futures. Note: CSI denotes ClarkSea Index; BDI denotes Baltic Dry Index; BCTI denotes Baltic Clean Tanker Index; BDTI denotes Baltic Dirty Tanker Index



(a)



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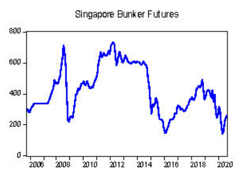
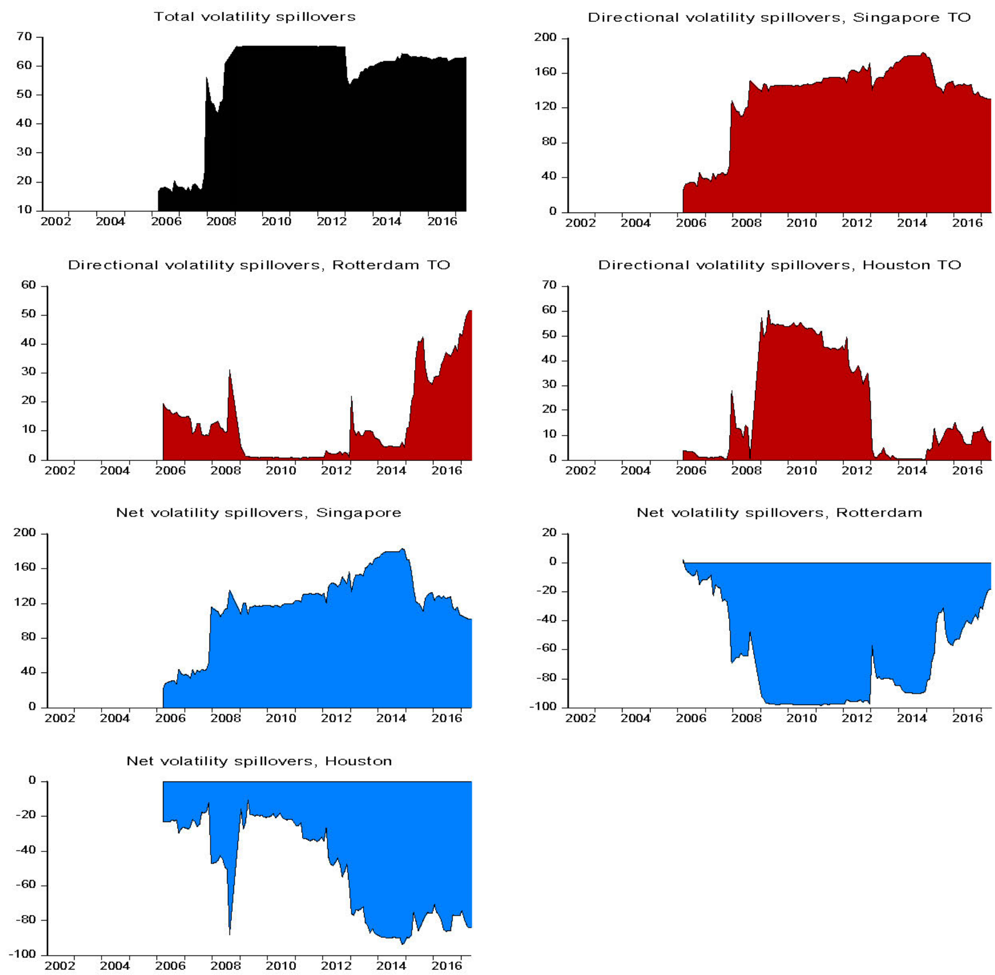


(c)

Figure 2 The total, directional, and net spillover indices among the three leading bunker markets - Singapore, Rotterdam and Houston



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