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The complex network analysis of liner shipping networks: Lessons from the merger between COSCO and CSCL

Liehui Wang, Nanyi Zhang, Fei Ye, Yui-yip Lau, César Ducruet

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Abstract: COSCO and China Shipping Container Lines (CSCL) are leading enterprises in China's shipping industry. They merged and reorganized as COSCO Shipping Lines in 2016. Through using a complex network methodology, we analyze the spatial patterns of their shipping networks before and after the merger. We evaluate the integration effects based on two main dimensions: network and hub economies. While complementarities are found between COSCO and CSCL networks before the merger, COSCO Shipping Lines increased the total number of service nodes and shipping routes significantly. The merger also had the effect of strengthening the hub capacity of 7 of the top 15 hub ports in the main markets covered by the new company. Results underline that this strategy of overseas pivotal ports promoted the development of hub economy and regional market expansion.

Keywords: corporate merger, shipping network patterns, complex networks, COSCO Shipping Lines

1 Introduction

In the liner shipping business, the performances of shipping firms rely on their conduct of taking such decisions as capacity and pricing level. From the mid-1990s onwards, a tendency towards mergers and acquisitions has spread quickly across shipping firms (Yip et al., 2012). After the global financial crisis in 2008, the shipping market was generally oversupplied. Against the backdrop of performance losses and financial constraints faced by most shipping companies in 2016, the industry underwent a consolidation and reorganization. The ultimate objective was to solidify their competitive position against competitors (Yip et al., 2012). Typical examples of such mergers and reorganizations include the French company CMA-CGM merged among Neptune Orient Lines, the Norwegian Solstad Offshore, and REM Offshore; NYK (Nippon Yusen Kabushiki Kaisha) and MOL (Mitsui O.S.K. Lines) integrated with Kawasaki steam ship and its consignment business, STX marine shipbuilding's self-rescue reorganization plan; and Hapan-Lloyd, integrated with UASC (United Arab Shipping Company) and Maersk Line consolidated with Hamburg Süd Group.

Following this trend, China merged and reorganized its major shipping giants, namely COSCO and CSCL, renamed as COSCO Shipping Lines. COSCO and CSCL were China's largest shipping companies in 2015 while ranked sixth and seventh in the world, respectively. From the 1st March, 2016, COSCO Shipping Lines entered a transition process through the integration of shipping routes and the leasing of container ships formerly operated by CSCL. It also began to integrate the assets within the CSCL networks gradually according to its restructuring plan. COSCO Shipping Lines had formed a new shipping network structure by December 2016.

Recently, merger and reorganization activity among shipping enterprises has surged. Some research studies (e.g., Drahokoupil, 2017; Yeong and Jung, 2017; Onwuegbuchunam et al., 2018) have put forward different views on the merger of COSCO and CSCL. But, there have been few studies to review and analyze the development and formation of shipping networks (Lau, 2018). Some scholars have begun to study the impact of shipping alliances and restructuring activities on shipping structures. However, this has been limited to the qualitative explanation of the changes in global shipping capacity patterns in the context of corporate restructuring. Scholars have also explored the development of specific shipping companies in the context of mergers. The focus has been on the use of long-term stock and financial data to examine the economic benefits, whereas, changes in market capacity patterns have only been examined in brief overviews of the restructuring of the enterprise. The merger and acquisition dynamics in the shipping sector are classic topics, but lost ground from the 1960s to the 2010s due to the emergence of complementary approaches (Lau et al. 2018). Thus, even in the case studies of the globalization of the shipping networks of a single shipping enterprise, there is still a lack of a specific characterization and quantitative analysis of the key changes in shipping networks structure. Furthermore, the spatial patterns of Chinese companies' shipping networks have been under-researched.

This study employs a complex network approach to analyze the effects of company integration on the spatial patterns of shipping networks in the case of China's shipping industry. In doing so, we investigate port connectivity and explore the development of hub ports in affected regions. In addition, we discuss the underlying operational factors used by actors to design and develop their shipping networks, in terms of firm performance, capacity, network configuration, transit time, geographical coverage, and transportation time (see Jiang et al., 2015; Tu et al., 2018)

The rest of the paper is organized as follows. Section 2 includes a literature review. Section 3 presents our data and methodology. Section 4 provides a comprehensive analysis results about the shipping network structures of COSCSO and CSCL in 2015 and COSCO shipping lines in 2016. After Section 4, discussion and conclusion delivers in Section 5.

2 Literature review

2.1 Industry changes

There are three main approaches in which shipping companies can expand their markets, namely: alliances, mergers and acquisitions (M&A) and internal growth. The research on mergers and reorganizations of shipping companies and their alliance strategy has mainly focused on the motivation and impact factors (Rodriguez-Pose and Zadermach, 2003; Frémont, 2009; Fusilo, 2009; Das, 2011; Andreou, Louca, and Panayides, 2012; Wang, 2012; Choi and Yoshida, 2013; Alexandrou, Gounopoulos, and Thomas, 2014). Frémont (2009) explored the actual development of vertical integration of shipping companies and found that, in practice, shipping companies participated in intermodal transport in order to develop their core container shipping business. Based on the study of the motivation and purpose of M&A in shipping companies, Fusilo (2009) quantitatively verified the determining factors (i.e., technical, regulatory environment, and industry demand) of US shipping companies' M&A based on the neoclassical model. Rodriguez-Pose and Zademach (2003) adopted econometric models to examine the impact of geographic dimensions on corporate M&A activity. Das (2011) concluded that alliances can expand market coverage while M&A can achieve a higher synergistic economy. Andreou et al. (2012) suggested that companies

pursue economies of scale while striving towards economies of scope.

Utility analysts have paid more attention to the economic benefits of M&A after the reorganization of the enterprises. Alexandrou et al. (2014) systematically explored the benefits of M&A on the basis of the valuation benefits of the financial indicators of shipping companies involved in them. Choi and Yoshida (2013) examined through the M&A process of Japanese shipping companies and evaluated the effects of M&A through changes in a series of financial data. The merger of corporate induces a change in the market capacity pattern and an increase in the profitability of enterprises by improving asset utilization. The achievement of synergy is the main driving force for M&A and the evaluation criteria for the success of enterprise integration.

2.2 Shipping networks from an industry perspective

Research on shipping networks has focused on global, regional, and national scales and identified key factors determining the allocation of liner services under regional differences. Geographers in particular have been particularly keen in studying the globalization of liner shipping networks from an industry perspective. Slack and Frémont (2009) studied the container shipping development focusing on the evolution of major shipping companies in the past 50 years. Frémont (2009) analyzed the differences and characteristics of horizontal and vertical integration among types of shipping enterprise integration. Also, the study explored the main process of vertical integration by using a large scale of survey and in-depth interviews with various employees in shipping industry.

In addition, Frémont (2007) selected a single shipping company as a research target to explore the evolution of the enterprise shipping networks pattern, acquisition, route planning, and new liner operational mode. He particularly underlined how the hub port strategy played an important role in the formation of the shipping companies, with a focus on Maersk Line and CMA-CGM's global networks structure (see also Frémont, 2015). In addition, Parola and Veenstra (2008) sorted through the global landscape of major liner companies and terminal operators. Overall, these studies on shipping companies inclined towards the development of shipping companies by using simple statistical analysis or the evolution of global markets for shipping companies through the case study approach like Maersk Line and CMA-CGM.

Other geographers discussed changes in the port networks of specific companies such as COSCON and Evergreen in a comparative perspective along the Europe-Asia route (Comtois and Wang, 2003) and in relation to China (Rimmer and Comtois, 2005). Interestingly, only one study looked at the effect of alliances on shipping network structure, through a comparison between the Caribbean and Mediterranean basins (McCalla et al., 2004), concluding that the Caribbean network is more vulnerable due to its higher reliance upon such alliances. Last but not least, Metge and Ducruet (2017) analysed the port networks of major shipping lines across the whole African continent using cartography and correlation analysis, pointing to overlaps and differences in terms of main hub ports and outlying firms.

2.3 Graph theory and complex networks

Increasing computational power as well as newly available data (e.g. vessel movements, shipping schedules) allowed for more quantitative analyses of shipping networks and to shift from case studies at the local level to global-level studies mixing all major companies. Tools from graph theory, a branch of mathematics, and from complex networks, a branch of physics and computer

science, served to measure the centrality of port nodes and the structure of such composite networks. In doing so, research on the spatial patterns of shipping networks and global shipping networks in specific regions has become an emerging trend. Wang (2008), Kaluza et al. (2010), Ducruet and Notteboom (2012), and Xu et al. (2015) described the pattern of global shipping networks through a number of indicators such as degree of distribution, clustering coefficient, primacy ratio, and other indicators of centrality. Ducruet and Notteboom (2012) also pointed out the fact that East Asia is developing rapidly. Wilmsmeier and Notteboom (2011) compared the regional differentiation of liner shipping networks in South America and North Europe. The research study further discussed the liner shipping allocation factors from the different perspectives of port environment, contact with the hinterland, market operator strategy, and government policy.

Based on complex network theory, Chen and Hu (2016) analyzed the complex network characteristics of the Southeast Asia shipping networks along Maritime Silk Road. They highlighted that Singapore, Port Klang, and Tanjung Pelepas were all significant in the regional network (see also Wang et al., 2018). Based on the schedule of ships, Wang and Hong (2016) selected complex network indicators to describe the spatial structural change of the container port system on both sides of the Straits. According to the complex network method, Du et al. (2016) studied the spatial pattern of China's container shipping networks through a comprehensive analysis of overall network indicator degree, degree of distribution, and port centrality. Ducruet and Wang (2018) proposed an analysis of China's overseas connectivity based on various methods including single linkage analysis, over the periods 1890-2008 for all ships and 1977-2016 for containerships, shedding new light on the external hub ports concentrating flows such as Hong Kong, Busan, Kaohsiung, and Yokohama.

Based on shipping company schedules, this study combines complex network indicators, VOSviewer and Arcgis visual analysis to describe the spatial patterns of shipping networks accurately and explore the shipping routes of COSCO Shipping Lines, which reached the fourth rank in the world after the reorganization of the two former companies.

3 Data and methodology

3.1 Background and data

Shipping routes are a very important resource for a shipping company as they affect income and cost as well as business model feasibility. The shipping network's space pattern directly reflects the service scope and market coverage of the enterprise and is the intuitive response of the enterprise in pursuing economies of scope and scale. Based on the volume of shipping and the length of routes, global container shipping networks encompass two levels of organization: main routes and regional feeder routes. Main routes generally refer to East-West trunk lines of the northern hemisphere connecting Far East, North America, and Europe with each other, while regional feeder networks are mainly composed of North-South services connecting the northern hemisphere with Africa, South America, Australia, but also South-South routes (Wang, 2012). Accordingly, we define the main shipping markets of COSCO and CSCL as: East Asia, Southeast Asia, South Asia, the Middle East, the Mediterranean, Northwest Europe, North America East Coast, and North America West Coast as well as the secondary markets as: Australia, New Zealand, East Africa, West Africa, South America East Coast, and South America West Coast.

We collected the shipping schedules from COSCO and CSCL in October 2015 as well as

COSCO Shipping Lines in December 2016. In 2015, statistics show that CSCL had 151 ports and 691 routes and COSCO had 142 ports and 670 routes. After the merger in 2016, COSCO Shipping Lines had 200 ports and 1,316 routes. We merged the data for terminals at the same port and then used the port as the node in the network. The edge of the network between the two nodes is established if there is a route between the two nodes. The number of routes is the weight of the edge. By using Gephi 8.0.2 software, we constructed the directed and weighted networks of the two shipping companies in 2015 and COSCO Shipping Lines in 2016. The shipping network was created based on ports of call and the moving tracks of container ships. The moving tracks of container ships generated the links of port-to-port according to the successive ports of call (namely from port A to port B and from port B to port C). With the utilization of quantitative analysis, we explored the spatial structures of the shipping networks of the two companies from the perspective of the transportation network economy.

3.2 Methodology

Based on the transportation characteristics and the scale-free characteristics of complex networks, a few hub ports play leading roles in the overall network in the context of economies of scale and scope (Rong, 2001). Under complex network methodology, economies of size and capacity are the key elements of studying shipping networks. This study mainly concentrates on the changes in the ports and the routes connections of shipping networks. These changes represent the market coverage of the shipping networks and capture the size of the shipping networks. The economy of capacity identifies the phenomenon where the average cost gradually declines when the port increases its capacity in the networks to handle and transfer passengers and cargo, to compile trains, to load vehicles, to take off and land, and to dock ships. The two factors considered in this paper are the number of ports connected to a certain port and the frequency of routes passing through the port. The route frequency refers to the number of ships passing through the shipping route over a particular period. We can explore the changes in hub capacity during the port route integration process through the port strength variation index Ki.

Where: K_i=K_{i1}+K_{i2}, K_{i1}= (2016D_i-2015$D_i$max)/2015$D_i$min,

$$K_{i2}= (2016S_i\text{-}2015S_i\text{max})/2015S_i\text{min}. \tag{1}$$

When the port only has one company calling in 2015:

$$K_i=2016D_i/2015D_i\ +2016S_i/2015S_i.;$$

Where: D_i of node i is defined as the number of other nodes connected to that node. S_i is the sum of the number of edges that connect node i to all other nodes in the network. The calculation step is shown in Equation 2.

As can be seen in Table 1, based on the size of the index K_i, the port route changes are divided into five main categories: reduction, high intensive growth, low intensive growth, fully integrated growth, and expansion growth. The port change index is the amount of change in port connectivity in the shipping network. The categories of port change index reflect whether the port connectivity has increased and the levels of growth after the change of shipping network. Based on the positive and negative level of change, the connectivity of the port is classified as the reduction and growth. Taking the multiple of increments as the classification criterion, the growth of the port's connectivity

is classified as an intensive, a fully integrated, or an expansion.

Table 1. Evaluation of Port Change Index

Ki	Categories	Explanations
$K_i \leq 0$	Reduction	In 2016, the port route was weaker than/equal to the maximum strength of the port route for the two enterprises in 2015.
$0 < K_i \leq 1$	High intensive growth	In 2016, the port route was more than the largest anchor strength of the two companies in 2015 and the integration of the two companies was high.
$1 < K_i < 2$	Low intensive growth	In 2016, the port route was more than the largest anchor strength of the two companies in 2015and the integration of the two companies was low.
$K_i = 2$	Fully integrated growth	The strength of the port route in 2016 was equal to the overall level of full integration of the two companies' routes in 2015.
$K_i > 2$	Expansion growth	In 2016, the port route intensity was stronger than the overall level of full integration of the two companies' routes in 2015.

Complex network indicators include degree, weighted degree, and betweenness centrality. The Degree is an important indicator to describe complex network nodes. The degree Di of node I is defined as the number of other nodes connected to that node. The greater the degree of the node, the closer the node is to the other nodes in the network and the more likely it is to act as a hub towards its immediate neighbors. In container shipping networks, the degree of the port is captured by the number of connecting ports. It indicates the contact range of the port. In the regional container networks, there is often more than one route connecting two ports. Additionally, the connection between ports has a weighted relationship among the number of routes. The node degree value can represent the significance of the nodes in the unprivileged network, reflecting the close relationship between a port and the rest of the ports within a port system. Importantly, the node weighted degree more accurately expresses the strength of the node connection in the weighted network to consider the frequency of the port-to-port relationship. Therefore, in this study, the weighted degree of the port definition is (Fusilo, 2009):

$$Si = \sum_{j \in N} Wij \tag{2}$$

W_{ij} represents the weight of the connection between node I and other nodes j in the network. The strength of the node association S_i is also named in the weighted degree in Gephi software. It indicates the sum of the number of edges that connect node I to all other nodes in the network.

Betweenness centrality mainly highlights the influence of the nodes in the whole network. It is an important parameter of network centrality and is used to indicate the strength of indirect connections between nodes. In general, hubs are nodes with a large betweenness centrality. The betweenness centrality of node I refer to the proportion of the number of nodes i in the shortest paths in the network. The number of nodes I is mathematically expressed as follows (Fusilo, 2009):

$$C_{Bi} = \sum_{k,j} \frac{\sum_{l \in S_{kj}} \delta_l^i}{|S_{kj}|} \tag{3}$$

Where in S_{ki},k, i is a combination of the shortest paths; $\sum_{l \in S_{kj}} \delta_l^i$ is the sum of the shortest paths through node i. In shipping networks, the greater in the betweenness centrality of a port infers the stronger in the accessibility between that port and other ports, and the stronger its global hub function.

4 Main results: shipping network structure before and after the merger

4.1 Difference in network structure of COSCO and CSCL in 2015

Table 2 compares the regional coverage of COSCO and CSCL in terms of ports of call. The two shipping firms had a high degree of commonality in North West Europe and Australia where the proportion of the same ports owned by COSCO and CSCL were 0.91 and 0.78, respectively. For West Africa, East Asia, North America, and South Asia, the overlap is noticeable, with a proportion ranging between 0.6 and 0.67. Their differences are mainly demonstrated in the following. CSCL had the advantage of port coverage in the Mediterranean, the Middle East, South America East, and North America East. COSCO's network is more developed in Southeast Asia, while the proportion of the same ports owned ranged from 0.36 to 0.46. The difference in port selection was the largest in the West Coast of South America where the overlap was only 0.29.

Table 2. COSCO and CSCL covered Ports in 2015

Navigation Area	No. COSCO ports	No. CSCL Ports	No. call the same port	Total no. ports	Share of the same port calls (%)
Northwestern Europe	11	10	10	11	0.91
Australia/New Zealand	8	8	7	9	0.78
West Africa	4	6	4	6	0.67
East Asia	31	32	25	38	0.66
North America West	10	11	8	13	0.62
South Asia	4	4	3	5	0.6
The Mediterranean	14	21	11	24	0.46
Southeast Asia	22	9	9	22	0.41
East Africa	4	3	2	5	0.4
Middle East	13	19	9	23	0.39
South America East	7	11	5	13	0.38
North America East	8	11	5	14	0.36
South America West	4	5	2	7	0.29

Notes: The share of calls on the same port is the ratio of the two shipping companies' port calls (i.e. the same port) in the total number of the two shipping enterprises' ports.

The distribution between the two companies of the ports with important connections (weighted degree greater than 10) shows remarkable spatial differences. According to Figures 1 and 2, the two shipping firms formed critical port connections in China's coastal areas and Southeast Asia. CSCL had relative advantages in the Mediterranean, the Middle East, and Northwest Europe. COSCO had relative advantages in North America and Australia. However, neither company formed an important port network in South America or Africa. The important port connections (weighted degree greater than 10) are mainly related to the east-west shipping markets such as East Asia-North America West Coast, East Asia- Southeast Asia, Southeast Asia-the Mediterranean, and the Mediterranean-South American East Coast. The CSCL network in China-Australia-Southeast Asia and North America West-North America East shows relatively frequent contact.

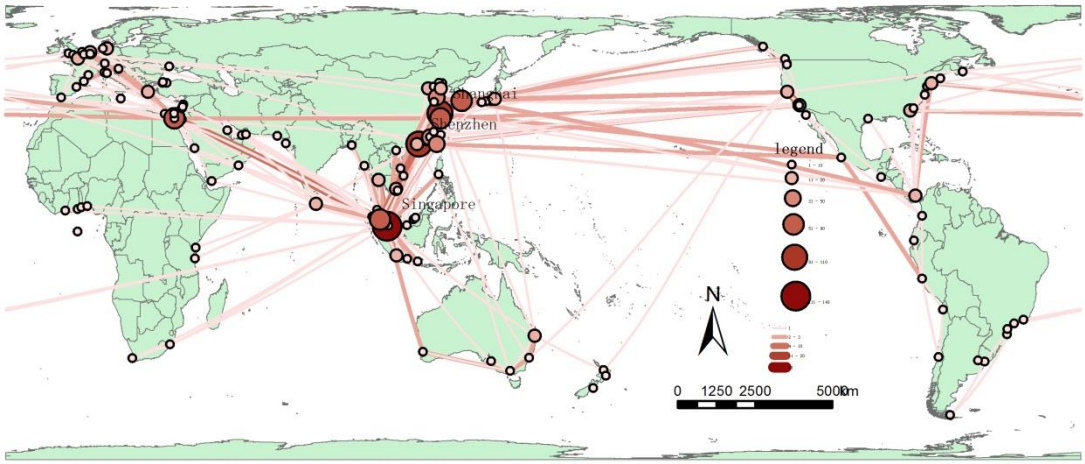

Figure 1. Shipping network of COSCO in 2015 based on weighted degree

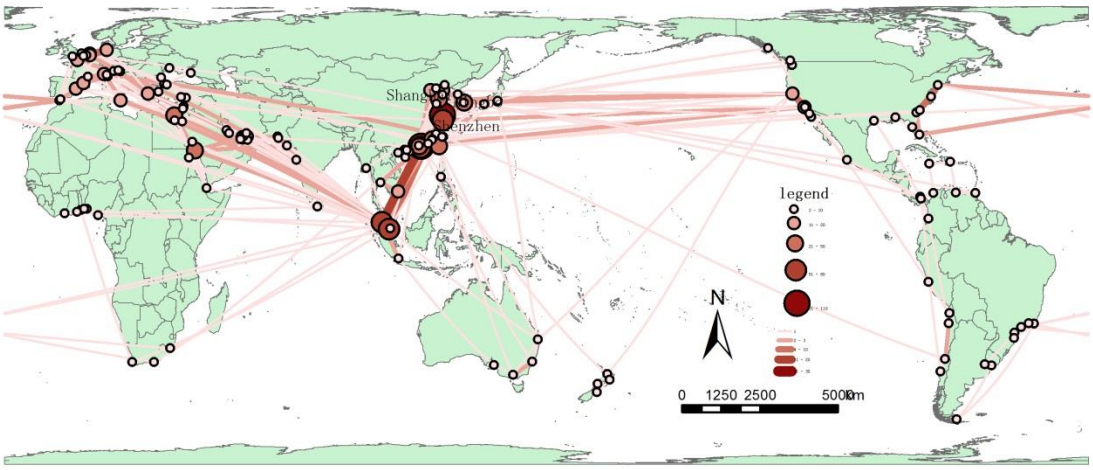

Figure 2.Shipping network of CSCL in 2015 based on weighted degree

In summary, the two shipping firms called the ports independently on the edges of the shipping networks. The shipping networks of the two shipping firms mainly focused on the main market. Although COSCO and CSCL showed commonalities in the main market, they still had different advantages in specific ports and areas. Moreover, the differences between the two shipping firms stood out clearly in the secondary markets from the north to the south.

4.2 Port increase and route expansion for COSCO Shipping Lines in 2016

We analyzed the economies of size of shipping networks based on the increase and decrease

in the number of port calls. During the restructuring of the COSCO Shipping Lines' networks, the increasing number of port calls showed an expansion of size. But, an expansion in secondary markets was not obvious and new port connections remained low. As shown in Figure 3, the additional 39 ports of COSCO in 2016 mainly concentrated on main markets compared with 2015: North West Europe (10 ports), the Mediterranean (9 ports), North America (4 ports), Australia (3 ports), South America East (3 ports), South Asia (2 ports), and Southeast Asia (3 ports). One new port was added to East Asia, the Middle East, North America West, and West Africa respectively. In addition, only one or two routes passed most of the ports. There were 22 ports where the numbers of ports of call were cancelled. It mainly occurred in North and South Asia, followed by two ports in Southeast Asia, the Mediterranean, the Middle East, and East Africa respectively. Also, one port was dropped in South America East, North America East, and South America West respectively. Among them, Pasir Gudang port in Malaysia, and Port of Sohar in Oman, Rio de Janeiro in South America were among the dropped significant ports. The changes in ports of call in the shipping networks are the basic reflection of market expansion. The expansion of shipping networks has shown that the integration of the two shipping firms achieved a considerable expansion.

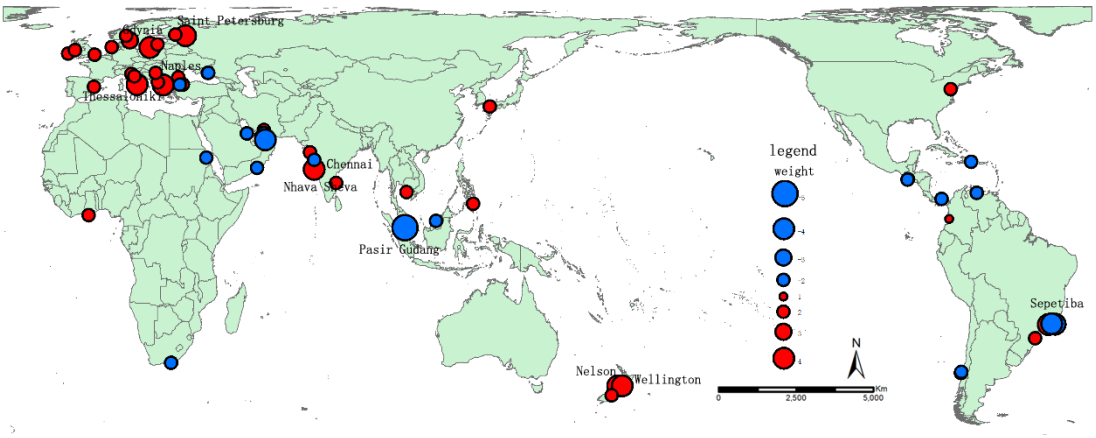

Figure 3. Changes in ports covered from 2015 to 2016

Notes：Red indicates an additional port, blue indicates reduced ports, and symbol size is the relative size of port degree value, indicating the corresponding connectivity of the port in the network.

In 2016, COSCO Shipping Lines had the widest coverage in the Mediterranean and East Asian navigation areas, followed by Southeast Asia, North West Europe, and the Middle East. North America, Australia, New Zealand, and South America East coast networks also exhibit wide coverage. COSCO Shipping Lines maintained its dominant position in the main market while expanding its coverage towards several additional ports in secondary markets.

We analyzed the changes in the size of the shipping networks from the sum of the frequency of any two ports. In 2016, COSCO Shipping Lines significantly enlarged its route links and the overall network gained economy of size. The frequencies of COSCO's and CSCL's shipping routes in 2015 were 670 and 691, respectively. After integration, the COSCO Shipping Lines networks dramatically increased to 1316 in 2016. Based on our analysis, only the links of port-to-port were considered. In 2015, the number of ports by COSCO and CSCL was 142 and 151 respectively. In 2016, the number of the ports with COSCO Shipping Lines was 200. From the perspective of the direct connections of various shipping networks in 2016, the COSCO Shipping Lines route interval contact among Southeast Asia, Australia, New Zealand and other navigation zones did not change.

Surprisingly, the other navigation zones expanded their scopes. According to Figures 4 to 6, the expansion of Mediterranean connections was the most evident. New direct links were established with four regions including West Africa, South America, and South Asia. As a result, shipping networks attained a wider range of route connections. Closer connections were observed in the shipping patterns of COSCO Shipping Lines. In 2016, Southeast Asia-East Asia and East Asia-North America West were closely associated, followed by the Middle East-Southeast Asia, Southeast Asia-South Asia, the Middle East-the Mediterranean, and North-West Europe- the Mediterranean.

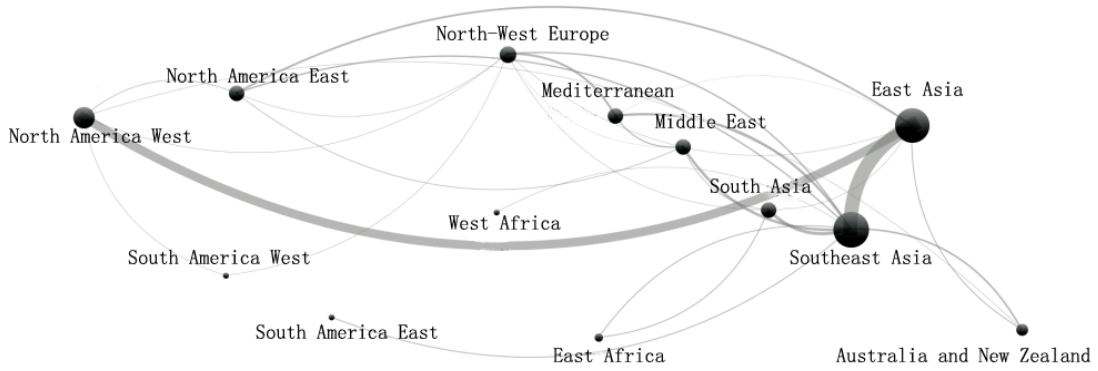

Figure 4. Links between different COSCO navigation areas in 2015

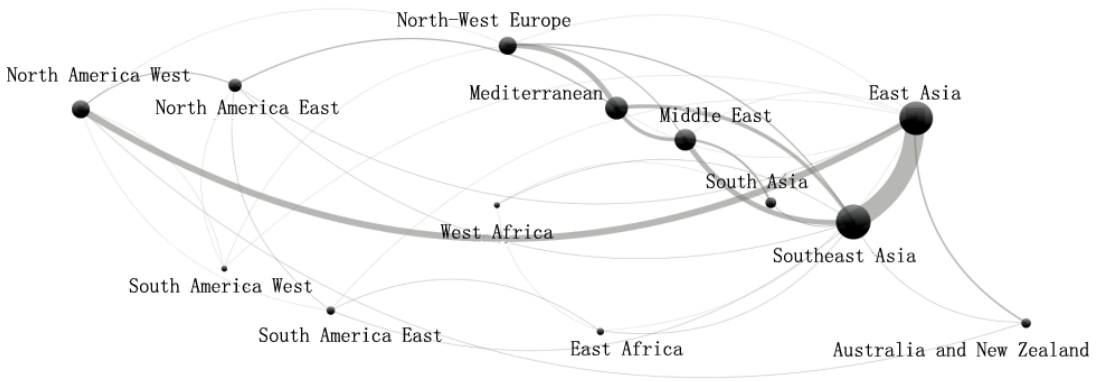

Figure 5. Links between different CSCL navigation areas in 2015

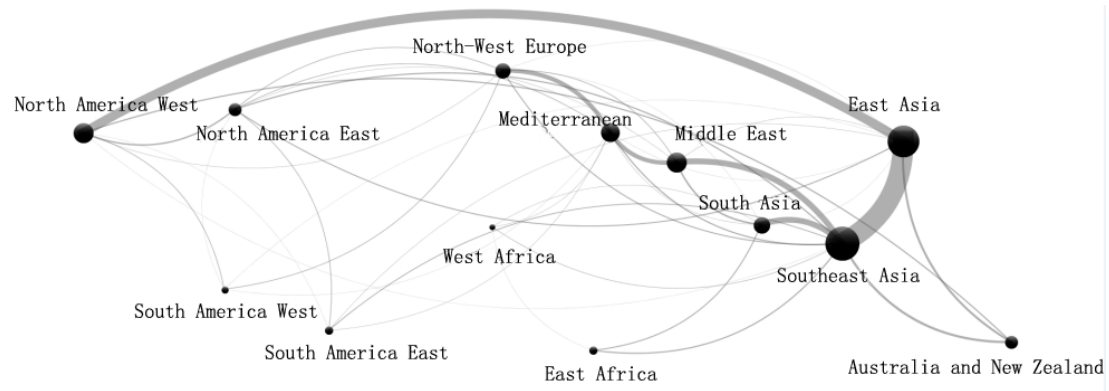

Figure 6. Links between different COSCO Shipping Lines navigation areas in 2016

4.3 Port hub enhancement in 2016

The two factors of port connection degree and route frequency are considered. According to the size of the port strength change index Ki, the port integration changes were divided into five categories: reduction, high intensive growth, low intensive growth, fully integrated growth, and expansion growth. These portray changes in hub capacity are provided in the integration process 2015-2016.

In 2015, a total of 161 ports from COSCO's and CSCL's networks were included in the 2016 COSCO Shipping Lines' networks. After the integration of the routes, there were 70 ports with expansionary growth, 27 ports with fully integrated growth, 21 ports with low intensive growth, 24 ports with high intensive growth, and 19 ports with reduction. This means that only 12% of the ports showing the routes were under contraction. The ports with significantly enhanced hub capacity are shown in Figure 7. These are mainly distributed in Southeast Asia, the Mediterranean, Australia and New Zealand, the Middle East, West Africa, South America, and North America. Ports exhibiting weak hub capabilities were mainly located in North West Europe, the Mediterranean, North America, the Middle East, and the East Asian navigation zones. It should be noted that China's domestic network and its ports are excluded from the analysis. The ports in the Mediterranean and the Middle East changed significantly. Overall, main markets such as Southeast Asia, the Mediterranean, and North America significantly strengthened their hubs during the integration process while secondary markets like West Africa and South America East coast were also strengthened.

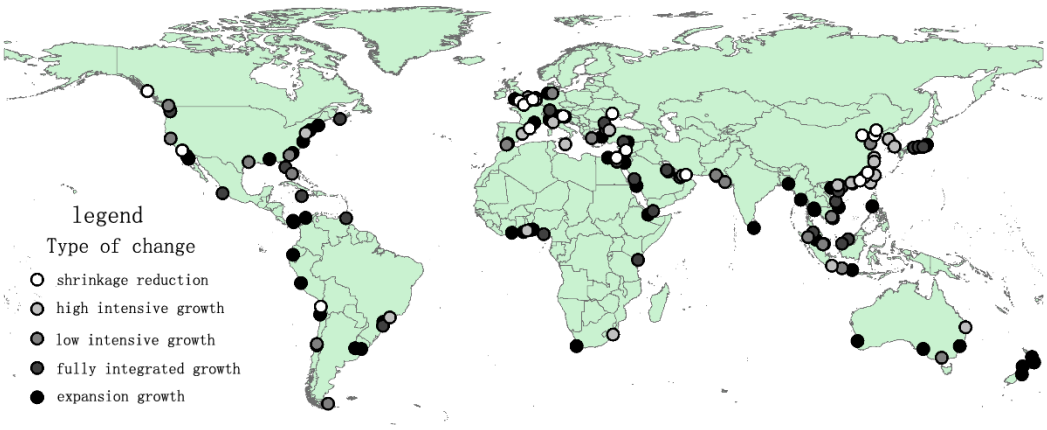

Figure 7. Changes in ports from 2015 to 2016 by port change index

After the shipping networks integration of the two shipping firms, the ports with important connections (i.e., weighted degree greater than 10) were mainly concentrated on the main east-west market. Australia and New Zealand showed important links, as well as South America and Africa, which initially formed ports with pivotal connections. According to Figure 8, the important ports were addressed in East Asia where it includes 16 important ports in China's coastal areas and in surrounding areas such as Kaohsiung and Busan. There are nine important ports in Southeast Asia, notably strategic transhipment ports such as Singapore and Klang. Nine ports are located in the Mediterranean of which Piraeus which is a key port in the region. Six ports are situated in North-West Europe. Rotterdam and Hamburg are considered as the centers of the region. In addition, there were 10 ports in North America, including 4 in the US East Coast and 6 in the US West Coast. Moreover, 4 ports in the Middle East consist of Jeddah Port and Port Said. In secondary markets, there were four ports with high port call frequency in Australia and New Zealand. Three of these

ports were strategic ports in the original COSCO shipping network. Two are in South America (Santos and Callao) and one is in Africa (Lagos). But, the overall network level was low. The connections of the high-frequency zone were not only limited to the port connections of the main east-west navigation area and the ports in the north-south navigation area, but also connected with other regions like West Africa-Southeast Asia, Australia-Southeast Asia and Australia-New Zealand-East Asia. Besides, the linkage between Australia-New Zealand-North America West, South America West-the Mediterranean, and South America West and North America West ports were highly intensive.

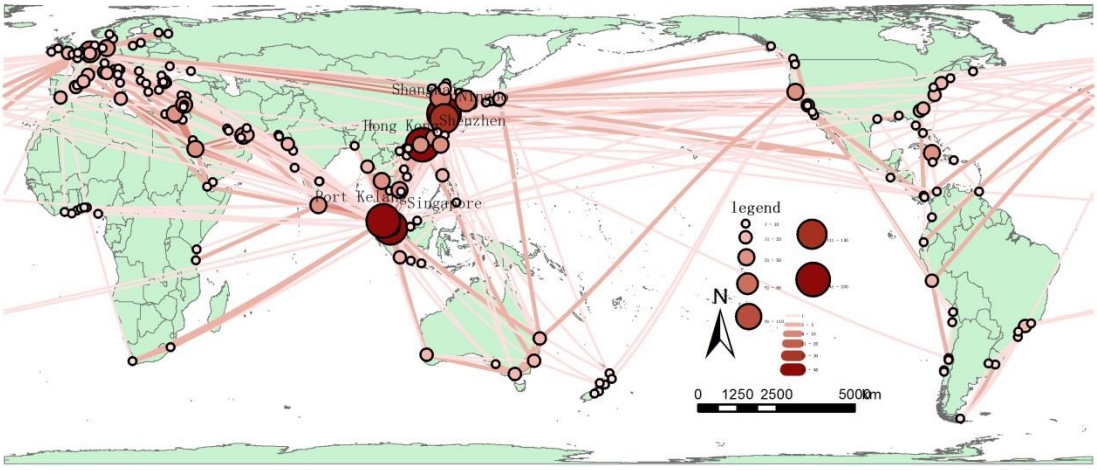

Figure 8. Shipping network in 2016 based on weighted degree

The scale-free characteristics of the shipping networks indicate that a small number of hub ports play a leading role in the entire shipping networks. In the transportation networks, the nodes with large betweenness centrality are generally recognized as hub nodes. We looked at the top 15 ports in terms of centrality in 2016 (see Table 3). There were 15 hub ports were changed including seven expansion growth, two with low intensive growth, five with high intensive growth, and one with reduction.

The calling strengths of hub ports with important network status, such as Colombo, Algeciras, Istanbul, Rotterdam, Klang, Piraeus, and Manzanillo (Mexico) increased significantly. This showed a growth trend in the COSCO Shipping Lines' networks. COSCO Shipping Lines used the 21st Century Belt and Road Initiative (BRI) as an important opportunity to integrate routes around the globe. It has set up 255 international routes and 146 domestic routes. The vessels operated by COSCO have docked with 356 ports in about 105 countries and regions around the world. The main shipping routes and terminals invested by COSCO were mostly distributed along the 21st Century BRI (Xu et al, 2015). The port of Colombo is a hub port for transit cargo in South Asia. It is a transhipment port for the world routes in Europe, Asia, the Pacific and Indian Oceans (Ducruet and Notteboom, 2012). Moreover, it is also a key hub port for China's economic development strategy for the BRI (Wilmsmeier and Notteboom, 2011). Algeciras is another key transport hub in the Mediterranean region. Its superior location conditions are attractive for shipping companies looking to expand markets from the north to the south (Frémont, 2007). COSCO chose Algeciras as an important port of call for the Strait of Gibraltar. At the same time, the Algeciras Port Authority opened a tender for its 50-year franchise for the public/private terminal. COSCO Shipping Lines intended to acquire the new terminal in Algeciras to consolidate its position in the Mediterranean shipping market.

Table 3. The top 15 ports by betweenness centrality port change index

Categories	Ports	Median Centrality	K_{i1}	K_{i2}	K_i
Expansion Growth	Colombo	0.061	1.500	9.000	10.500
	Algeciras	0.060	2.500	2.500	5.000
	Istanbul	0.068	2.400	2.000	4.400
	Rotterdam	0.103	1.364	1.900	3.264
	Klang	0.212	0.724	1.615	2.340
	Piraeus	0.199	1.300	0.786	2.086
	Manzanillo	0.094	1.000	1.000	2.000
Low intensive growth	Busan	0.117	0.714	0.703	1.417
	Singapore	0.435	0.267	0.968	1.234
High intensive growth	Hong Kong	0.052	0.318	0.656	0.974
	Shanghai	0.083	0.231	0.723	0.954
	Said	0.052	0.095	0.800	0.895
	Shenzhen	0.126	0.259	0.575	0.834
	Santos	0.069	0.286	0.500	0.786
Reduction	Ningbo	0.052	-0.750	0.000	-0.750

The port of Istanbul is located on the southwestern coast of the Strait of Istanbul. It controls the passage from the Mediterranean Sea to the Black Sea via the Marmara Sea. In 2015, COSCO acquired a 65% controlling stake in the container terminal in Istanbul, Turkey. Rotterdam is a strategic regional hub port in the North-West Europe region. It is considered as an important connection throughout Northwestern Europe to expand in the Nordic market. COSCO Shipping Lines acquired a 35% stake in Rotterdam Euromaxterminal in May 2016. The expansion of the European branch line further utilized Rotterdam's trans-shipment function. Klang is located at the Straits of Malacca connecting between the Indian and Pacific Oceans. It is a hub that competes with Singapore. In 2015, CSCL was mainly affiliated with Klang and Singapore in the Straits of Malacca. COSCO was mainly affiliated with Singapore. The two firms had the same routes in Port Klang. As the matter of fact, the low loading and unloading fees for Klang attracted the liner shipping routes (Frémont, 2007). Thus, the network status of Port Klang has increased during the integration process. Controlled by COSCO Shipping Lines and the construction of a sea-rail intermodal transport, Piraeus became a pivot port of the Mediterranean Sea near the Suez Canal (Frémont 2015). It relies on the Central European Land and Sea Express railway. This is significantly important for high-value commodities that are shipped in large volumes (Van der Putten, 2014). The objective is to connect among the Mediterranean Sea, the Black Sea, North America, West Asia, and Central and Eastern European countries is a highlight of the 21st Century BRI. It can enrich the port's value as a consolidation base for hub port (Van der Putten, 2014). Panama established diplomatic relations with China on June 13, 2017. Therefore, COSCO and CSCL had a few important transit ports in the Panama Canal and the Manzanillo port (Mexico) with relative call advantages in Latin America. In 2015, COSCO and CSCL had low commonalities but strong complementarily in Manzanillo. Thus, its port status has increased after the integration.

The philosophy of COSCO Shipping Lines for route design and port selection mainly included port cargo volume, loading and unloading costs, port conditions, and alliance factors (Parola and Veenstra, 2008). In order to gain the economy of scales and synergies, COSCO Shipping Lines

restructured the companies' common routes during the route integration process. Singapore, Busan, and Hong Kong were important hub ports in the networks and held strategic terminals for COSCO investment. Due to the high commonalities of routes, the combination of redundant routes during the integration process made port increased overall hub capacity significantly. Shanghai, Ningbo and Shenzhen were the main hub ports in China's coastal area. But, their status in the network analysis was relatively weak for the following reasons. On the one hand, this study excludes China's domestic trade routes 2016 for COSCO Shipping Lines. On the other hand, there were high commonalities in terms of route setting between COSCO and CSCL. Santos Port is the leading container port in South America but its terminal equipment is outdated, its infrastructure is insufficient, and its loading and unloading tools are antiquated. Therefore, its port throughput is low (Chen and Hu, 2016). At the same time, COSCO and CSCL showed commonalities in the Santos route. In 2016, COSCO Shipping Lines significantly increased ports of calls to other ports and hence, Santos Port's first position has decreased. Located in the Mediterranean at the northern end of the Suez Canal, Port Said is one of the world's largest trans-shipment ports. It was an important port of call for both COSCO and CSCL in the Suez Canal. However, the strategic position of the adjacent port Piraeus rose sharply while the shipping status of Said declined relatively.

5 Conclusions and discussion

In the context of COSCO and CSCL shipping firms' restructuration, the reorganization of the shipping networks was a key part of the integration of firm assets. Based on a complex network measurement, we draw the following conclusions by examining the shipping networks pattern and the network effects after integration.

- Our findings indicated that there was no high level of homogeneity between the shipping networks of COSCO and CSCL. Clearly, there were differences in firm marketing tactics. The main objective of a firm is to maximize the firm's profitability. It requires the firms to take a proactive attitude in response to different customer needs and market changes. Shipping companies align key resources to avoid a decline in firm performance (Nagya et al., 2017). However, COSCO and CSCL had both overlaps and differences. While the two shipping firms were similar in the main shipping market, they had different comparative advantages in specific ports and segments. Both COSCO and CSCL are now using customer focus strategies to increase their understanding of the specific customers' preferences and predict how it is likely to change in the forthcoming years. To this end, shipping firms are able to make use of required resources and skills to fulfil customer needs (Kaliszewski et al., 2020; Bhattacharya et al., 2018). Moreover, the differentiation between the two firms in secondary markets from the north to the south was obvious. The difference in the alignment of different navigation areas provided support for the reorganization and expansion of their original shipping patterns. The similarities in the main market routes identified that excess capacity appeared in the shipping market. The resources of the two firms in some routes were redundant. As a result, the reconfiguration structure could be optimized to improve the efficiency of route utilization.

- During the restructuring of the COSCO networks, the increasing number of port calls leads to expand the existing size of the network. The newly added ports were mainly concentrated on the crucial market areas containing North West Europe, the Mediterranean

Sea, and North America East. Regarding to the secondary markets, they were mainly concentrated in South America. In the meantime, the total number of shipping routes, the links of port-to-port and navigation links expanded significantly. Indeed, ports in different shipping zones also achieved a direct contact.

- In 2015, COSCO and CSCL followed the same market tendencies in their selection of ports in various shipping areas. This included a large proportion in the main market and a small proportion in secondary markets. Hence, their combination resulted in expanded port coverage, strengthened routes, and achieved economies of scale. In terms of port route, the ports with high similarity route were used to rationalize the network during the integration process in order to address redundant resources and integrate capacity allocation. In this process, secondary markets were strengthened to varying degrees, especially for South America and West Africa.

In the study of the globalization process of shipping firms, the hub port strategy played a vital role in the globalization of a shipping network based on internal growth strategies of firms such as the merging of CMA CGM and Delmas, as well as of Maersk Sealand and P&O Nedlloyd in 2005 (Frémont, 2015). The cultivation and selection of overseas hub ports were not only reflected in the overall increase in the network economy in the company optimization approach, but also generated the important strategy of exploring secondary markets under the effect of globalization. During the integration of COSCO and CSCL's routes, Piraeus and Rotterdam are important transhipment ports in the Mediterranean navigation area and the northwest European region respectively. The Algeciras and Manzanillo (Mexico) had transit impacts on improved connections between north and south markets. In the process of consolidating overseas markets and expanding secondary markets, COSCO Shipping Lines strengthened its overseas hub port strategy and selected ports with certain geographical advantages. A typical example is Algeciras, which participated in terminal operations and project cooperation.

In terms of study limitations, we analyzed shipping schedules but excluding other shipping factors such as ship capacity and sailing time. From the perspective of the route networks pattern, the overall operation of the shipping enterprise after reorganization could not be fully investigated. The actual overall pattern of the shipping industry globalization was limited due to the two firms involved in the restructuring of COSCO Shipping Lines that lacked a more comprehensive comparison. In future studies, we will consider other elements such as ship capacity and terminal operations to examine the overall pattern of the global shipping industry. The future M&A strategy means that shipping companies will open up new organic growth paths, markets and customers through acquisition. Its purpose is to boost up the economic growth and sustainable development of shipping enterprises in the complicated operating environment in the future. Therefore, M&A strategies will be continuously promoted. In addition to economies of scope and scale, operations management is also an important indicator that we can use to assess the impact of mergers and acquisitions on enterprises. After the merger, it is necessary to consider whether the information exchange and practices of shipping companies can fully solve various problems in the linkage and the overall operating efficiency.

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