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Dynamics of liner shipping network and port connectivity in supply chain systems: analysis on East Asia

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ABSTRACT

The study of ports in supply chain systems is an emerging area of importance which has drawn more attention from researchers in recent years. This paper presents a new perspective in this research area by examining the calling patterns of container shipping services in order to understand the dynamics of port connectivity and inter-port relationships in the supply chains. Empirical evidence is drawn from four major ports in East Asia, namely Shanghai, Busan, Kaohsiung and Ningbo. The study identifies the shipping capacity, trade routes and geographical regions connected to the ports, shipping lines involved, and the extensity and intensity of inter-port relationships among the four container ports from liner shipping network's perspective. The findings show that most of the shipping capacity employed on the major east–west trade routes became non-exclusive and involved calls at two or more of the four ports. Port planners, terminal operators and carriers could capitalise on opportunities through exploitation of complementary relationships that exist among the selected ports, such as offering a package for shipping lines to call at a portfolio of terminals owned by the same terminal operator. Policy and research implications as well as recommendations are discussed for various stakeholders concerned with port planning and regional development.

1. Introduction

Being an interface linking sea and land transport, a port is an integral platform serving as a base for production, trading, logistics and information transfer. As a node in supply chain systems that intersect between hinterlands, the performance of a port will have a direct impact on the competitive advantage of its users and affect the economic development of both the origin and destination hinterlands. The study of ports in supply chain systems is an emerging area of importance which has drawn more attention from researchers in recent years. This paper further develops this line of research and presents a new perspective by examining the calling patterns of container shipping services in order to understand the dynamics of port connectivity and inter-port relationships in the supply chains. Specifically, empirical evidence will be sought from four major ports in East Asia, namely Shanghai, Busan, Kaohsiung and Ningbo where the analysis will identify the shipping capacity, trade routes and geographical regions connected to the ports, shipping lines involved, and the extensity and intensity of inter-port relationships among the four container ports from liner shipping network's perspective. The study employs the method of analysing annualised slot capacity (ASC) offered by container shipping services for quantification and detailed investigation.

2. Snapshot of related literature

Previous studies conducted to analyse inter-port relationships focused mainly on the issue of port competitiveness and competition in the industry. The study approaches included routing strategy focusing on port selection based on optimisation of shipping network (Mourao et al., 2002; Zeng and Yang, 2002), multimodal models accounting for perspective of shippers through minimising costs for origin–destination traffic (Luo and Grigalunas, 2003), transportation networks considering the impact on port performance (Robinson, 1998, 2002; Lee et al., 2006), logit models that can determine outcome probabilities on routing choice (Veldman and Bückmann, 2003; Clark et al., 2004), port productivity and efficiency studies identifying determinants of port performance (Sachish, 1996; De and Ghosh, 2002; Sanchez et al., 2003; Tongzon and Heng, 2005; Trujillo and Tovar, 2007), cost comparison accounting for quantitative and qualitative factors (Baird, 2002; Lam and Yap, 2006), marginal cost pricing analysing dedicated container terminals (Haralambides et al., 2002), contestability in container handling market (Notteboom, 2002), game theory

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assessing port operators' strategies (Yang, 1999; Flor and Defilippi, 2003; Anderson et al., 2008), cluster analysis taking into account wide range of factors deemed to influence port competitiveness (De Langen, 2002) as well as cointegration tests and error correction models which use regression to test long-term and short-term port relationships (Fung, 2001; Yap and Lam, 2006). The method of analysing annualised slot capacity was used in two previous studies on container port competition in East Asia (Yap et al., 2006) and Southeast Asia (Lam and Yap, 2008) respectively, and a paper analysing ports' connectivity (Lam, 2011).

Studying ports as elements in the supply chain is a relatively new and growing research area. The literature, especially for the earlier years, involved largely in the exploration and conceptualisation stage. Research approaches included value-driven chain systems in which the port and its service providers to offer sustainable value to users against other competing chains (Robinson, 2002), case study of Port of Le Harve in the automotive supply chain (Carbone and Martino, 2003); market review of the integration issues on ports and terminals (De Souza et al., 2003); port development in the context of lean and agile logistics concepts (Paixao and Marlow, 2003); survey of port performance measurement to test the relationship between the parameters of supply chain integration and the parameters of port competitiveness (Song and Panayides, 2008) and discrete choice modelling of port selection in the supply chain context (Magala and Sammons, 2008). Slot capacity analysis employed in this study is a new method in researching ports in supply chain systems.

3. Data and research methodology

Data for annualised slot capacity (ASC) in terms of TEUs, i.e. vessel capacity in container liner services is computed and analysed. Such data can be computed in various ways to generate useful information. In order to understand the dynamics of inter-port relationships, the point of interest is to know the ASC connected to ports. Computation of ASC for k services calling at a port can be obtained with following formula:

$$\sum_{i=1}^{k} ASC_i = \sum_{i=1}^{k} V_i F_i \qquad (1)$$

where V denotes average vessel capacity and F denotes the frequency of call in a year. As a single service could be deployed in multiple ports, summation of annualised slot capacity that called at the ports would exceed 100.0%. Similarly, summation of ASC deployed on various trade routes connected to each port would also be higher than 100.0%. ASC connected to the ports is categorised by various trade routes, shipping lines/alliances, and whether the shipping services made exclusive or parallel calls at the ports. The method involves tabulating and analysing over 3000 container shipping services that called at the selected ports on an annual basis over a 12-years period from years 1995 to 2006. Computation and formation of this database took more than 2 years to complete.

The method of analysing ASC can reveal the connectivity of the ports in a systematic and quantifiable manner. This is useful for assessing the competitiveness of the ports as well as the developments of inter-port relationships from liner shipping network's perspective. Specifically, the data allows examination of changes in port calls by shipping services. In this study, complementarity in port calls is defined as services that are initiated or removed from both ports at the same time. As for competitive relationship in port calls, this can occur when services are removed from one port to call at the other or those that now include the other port in order to handle cargo directly. For instance, improving market share for exclusive calls at a port versus other ports indicates the port's increasing competitiveness. The method allows analysis into the networks of the target ports without the need for the access to sensitive data which is difficult, if not impossible, to collect. The data availability of this method greatly facilitates future studies which research on topics of a similar nature.

4. Container port landscape in East Asia

Referring to port throughput in 2009, half of the top 20 container ports are located in East Asia. This reveals the significance of the region in the container port industry. The scope of this study is centred on the Yangtze River Delta (YRD) in China with spectacular trade growth in recent years and those ports having close relationship with the region. Being the two dominant ports in YRD, Shanghai and Ningbo ranked as the second and eighth busiest container ports in the world respectively. While container throughput of both ports consists mainly of cargo generated from hinterlands that are served by the Yangtze River, container handling performance of these ports is also affected by developments in other major ports in the region including Busan and Kaohsiung which are respectively the fourth and ninth busiest container ports in East Asia.

Government authorities of South Korea named Shanghai as a significant threat to its position as the premier transhipment hub in Northeast Asia (Lloyd's List, 13 June 2003; CI Online, 9 December 2005). To counter the threat from Shanghai, Busan reduced port charges for transhipment cargo and provided monetary incentives to encourage shipping lines to increase their transhipment volumes at the port. In addition, Busan is also investing directly into smaller Chinese ports in order to secure cargo from these sources in a bid to entrench the port's hub status (CI Online, 20 March 2008). However, announcement by Shanghai International Port Group (SIPG) of its strategy to develop a coastal feeder network which is aimed at securing transhipment cargo for Shanghai from other coastal ports in China is likely to threaten the largest source of transhipment traffic for Busan and intensify competition between the two major container ports in East Asia (SIPG, 23 March 2008; Busan Port Authority, 29 November 2007).

Apart from Shanghai, there is also a considerable amount of inter-port dynamics occurring between Busan and Ningbo where the past years saw a number of carriers substituting calls at one port for the other. For example, MSC reportedly shifted its transhipment hub in East Asia from Busan to Ningbo in 2003 in view of congestion arising from typhoon damage and strikes by hauliers at Busan (Lloyd's List, 30 July 2003). However, the shipping line subsequently shifted its hub back to Busan in 2007 which was estimated to boost transhipment traffic handled at Busan by 400,000 TEUs or 7–8% of total transhipment throughput (CI Online, 12 April 2007). This move was also estimated to reduce the amount of transhipment containers handled at Ningbo by some 50%. In addition to MSC, other carriers reported to be involved in switching calls from one port to the other also included China Shipping and Fesco (CI Online, 18 August 2006).

As for Kaohsiung, the fact that 55% of the throughput consisted of transhipment traffic suggests shipping lines that called at Kaohsiung to be actively sourcing around the region and such cargo could also have been handled at other major ports in East Asia. Furthermore, analyses of shipping services that called in the region by Yap et al. (2006) revealed Kaohsiung to be an important load centre for the Europe–Far East and Transpacific trade routes accounting for 47% and 58% of ASC deployed respectively in 2001.

Hence, for this research, Shanghai, Ningbo, Busan and Kaohsiung are included in the analysis in order to provide a comprehensive coverage of the extent and intensity of inter-port dynamics among the representative container ports in East Asia. Together, the four ports handled 56.1 million TEUs and accounted for 43%

Fig. 1. Geographical location of the four major container ports in East Asia and their container throughput in 2009. *Source*: Compiled from Informa UK Ltd. (2010).

of total container throughput in East Asia in 2009 (Informa UK Ltd., 2010). The geographical location of the ports and their container throughput are shown in Fig. 1.

5. Empirical analysis

5.1. Overview of total annualised slot capacity connected to the ports

Upon computation and analysis, it is found that the container ports of Shanghai, Busan, Kaohsiung and Ningbo were connected to 13 trade routes which saw 108.0 million TEUs of ASC deployed by 104 shipping lines in 457 shipping services in 2006. The largest shares of calls are generally accounted by the largest container lines, i.e. Maersk Line, CMA-CGM and MSC. Slot capacity connected to the ports accounted by national lines typically number less than 30% of overall calls received. Fig. 2 shows that ASC connected to the four ports more than tripled in the period from 1995 to 2006. The annual average rate of growth for ASC deployed reached 20.3%. The changes in ASC that called at the ports show a similar development to that experienced for container throughput handled. Specifically, referring to Fig. 3, Kaohsiung received a major share of the capacity that called in the region in 1995 whereas ASC received by the port

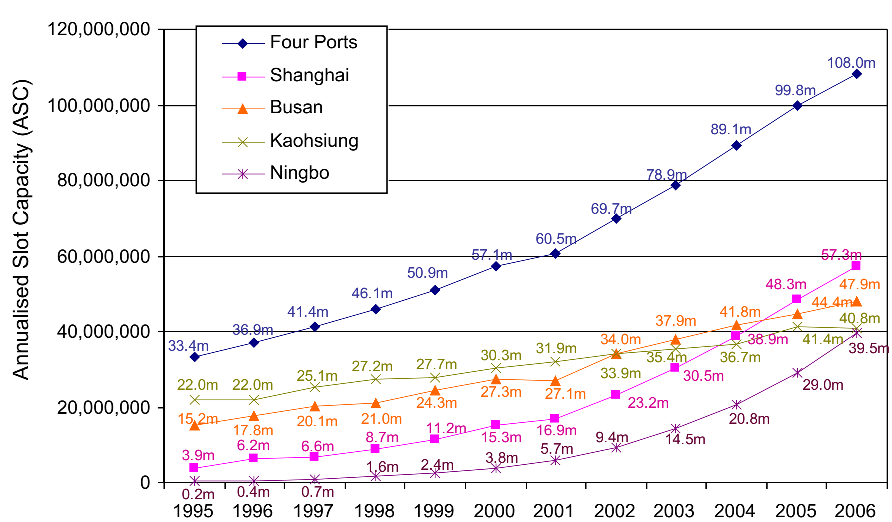

Fig. 2. Development of ASC which called at the selected ports in East Asia (in TEUs). *Source*: Authors' computation.

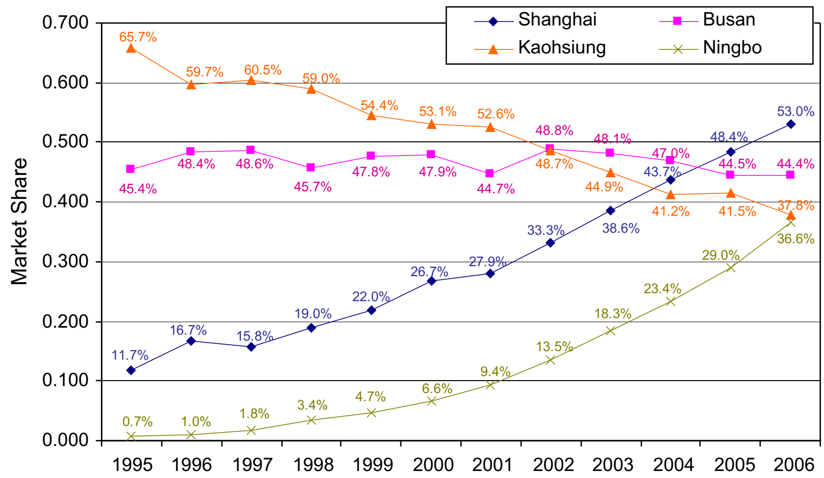

Fig. 3. Development in share of ASC connected to the selected ports. *Source*: Authors' computation.

fell to the third position by 2006 having been overtaken by Busan in 2002 and Shanghai in 2004. Even though the amount of shipping capacity that called at Kaohsiung almost doubled from 22.0 million TEUs in 1995 to 40.8 million TEUs in 2006, higher rates of growth experienced in the other ports saw its share of capacity received fall from 65.7% to 37.8%.

On the contrary, shipping capacity connected to Shanghai increased by 14.7 times from 3.9 million TEUs in 1995 to 57.3 million TEUs by 2006, representing the highest market share of 53.0% among the four ports. Constitution of shipping capacity that called at the port also changed from that which was oriented towards intra-Asian services to become an important port-of-call for services operating on key east–west trade routes. To a large extent, this development was made possible by new capacity that began to come on-stream at Waigaiqiao (phase 3 in 2002; phase 4 in 2004; phase 5 in 2005) and Yangshan (phase 1 in 2005) which enabled the port triple its container throughput as well. The performance registered by Ningbo was even more magnificent with ASC received rising by 178 times from a mere 0.2 million TEUs in 1995 to 39.5 million TEUs in 2006. As with Shanghai, profile of services that called at the port also changed from an intra-Asian nature to become a main port-of-call for the Transpacific, Europe–Far East and Mediterranean–Far East trades. The share of capacity received by the port also grew to reach 36.6%, which was almost on par with those calling at Kaohsiung. Regarding Busan, the profile of services that called at the port remained generally similar with the bulk of shipping capacity being contributed by shipping lines that operated on the Transpacific, Europe–Far East and Intra-Far East trade routes. As a whole, the period saw ASC received by the port tripling from 15.2 million TEUs in 1995 to 47.9 million TEUs in 2006 and maintaining a market share at about 44%.

5.2. Trade route analysis

Greater details can be obtained by further examining the trade routes which reveal the connectivity of ports by the geographical constitution. The ports under study are key nodes in the supply chains of east–west trades (refer to Table 1). As of 2006, 65% of their ASC was generated from east–west trades. The transpacific trade represented the highest volume with 44.9 million TEUs or 41.6% of ASC deployed. This was followed by the Europe–Far East (18.4%), Intra-Far East (13.2%), Southeast Asia–Far East (10.7%) and Mediterranean–Far East (7.8%) trades. The paper has chosen the top four trade routes for discussion which adequately cover east–west, north–south and intra-regional trades.

Table 1
ASC deployed on major trade routes connected to the selected ports in 2006. *Source*: Authors' computation.

Trade routes	Rank	ASC (TEUs)	% Share
East–West			
Transpacific	1	44,917,000	41.6
Europe–Far East	2	19,929,000	18.4
Mediterranean–Far East	5	8470,000	7.8
East–West Total		70,300,000	65.1
North–South			
Southeast Asia–Far East	4	11,601,000	10.7
Far East–Middle East	6	6212,000	5.7
Far East–Australasia	8	2686,000	2.5
Far East–South America	9	2354,000	2.2
Far East–ISC	10	1307,000	1.2
Others	–	944,000	0.9
North–South total		25,105,000	23.2
Intra-Regional			
Intra-Far East	3	14,233,000	13.2
Intra-Regional total		14,233,000	13.2
Grand total		108,036,000	100.0

The Transpacific trade was the largest trade that called at the selected ports with 88 liner services connected in 2006 (see Fig. 4). The trade experienced strong growth which widened the gap with the other trade routes reaching the extent that ASC connected was more than twice the volume of the second largest trade route. While most of the capacity called at Kaohsiung in 1995, the end of the period saw ASC called at Busan topping the list with a share of 53.3%. Furthermore, Busan was able to maintain its share of capacity received at above 50% throughout the period whereas Kaohsiung's slip from 78.3% in 1995 to 38.6% in 2006. Most of the capacity deployed by shipping services went from calling exclusively at Kaohsiung to making parallel calls at two or more of the four container ports, 78.2% of which included Busan. Kaohsiung was also overtaken by Shanghai in 2006. Inter-port dynamics were driven by attempts to capitalise on direct traffic generated from the immediate hinterlands as well as transhipment opportunities offered from the wider geographical region of East Asia. An increasing number of shipping lines were making direct calls at Busan and especially Shanghai in view of the larger container volumes that were generated at those ports.

The Europe–Far East trade was the second largest trade route with 19.9 million TEUs of shipping capacity deployed in 2006 which represented an annual average growth rate of 14.3% from 7.8 million TEUs in 1995 (refer to Fig. 5). A total of 27 liner services were connected to the ports, which was much lower than that of

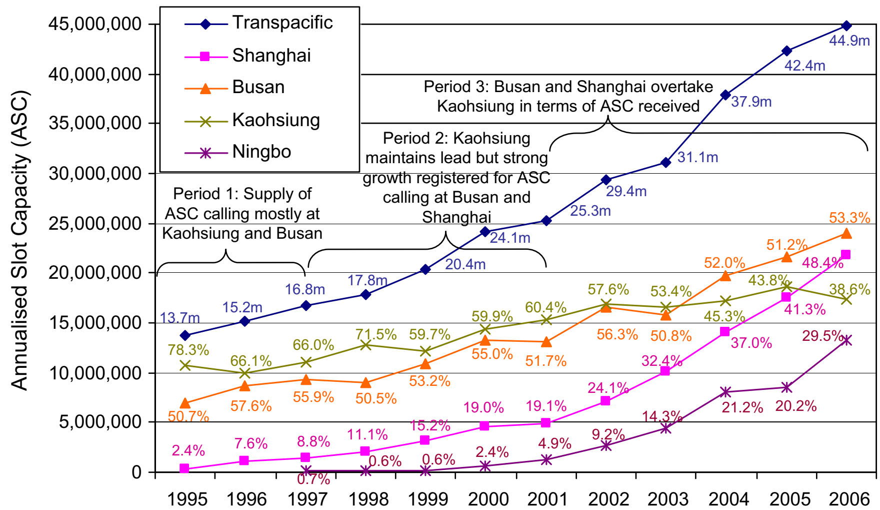

Fig. 4. Development of ASC deployed on the transpacific trade route connected to the selected ports. *Source*: Author's computation.

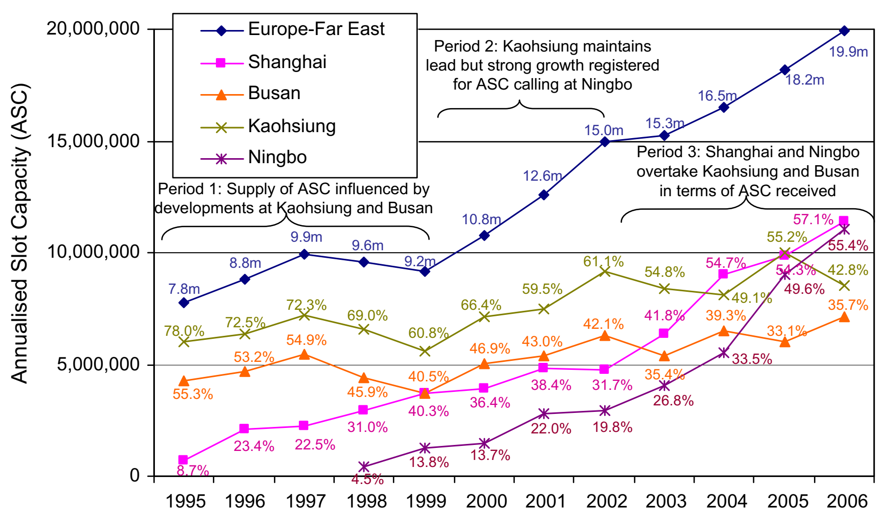

Fig. 5. Development of ASC deployed on the Europe–Far East trade route connected to the selected ports. *Source*: Author's computation.

the Transpacific trade, having 88 liner services connected. In the Europe–Far East trade, most of the shipping services which called at the selected ports were operated by carriers attempting to capitalise on direct traffic traversing between East Asia and Northwest Europe. With the exception of 1998, 1999 and 2003, the trade had been experiencing steady expansion in terms of ASC connected. However, the rate of growth experienced for this trade was one of the lowest compared to other trade routes and led to its share declining from 23.2% in 1995 to 18.4% in 2006.

The trend in overall performance for the period between 1995 and 2002 was influenced largely by events affecting capacity called at the container ports of Kaohsiung and Busan. However, stagnation in capacity expansion at both ports after 2002 and coupled with strong growth in ASC connected to Shanghai and Ningbo resulted in the two Chinese ports overtaking Kaohsiung and Busan to reach an unprecedented 11.3 and 11.0 million TEUs respectively. This allowed both ports to become the largest container ports connected to the Europe–Far East trade route in terms of ASC received. Furthermore, shipping capacity called at Shanghai and Ningbo were almost equal with 32.1% of total container shipping capacity making parallel calls at both ports.

Turning to the Intra-Far East trade, it was facilitated by 194 shipping services and accounted for 14.2 million TEUs or 13.2% of ASC connected to the four container ports in 2006 (see Fig. 6). The trade had been experiencing stable growth since 1997. The share of ASC accounted by the ports had been fairly consistent throughout the period of analysis with the largest share received by Busan, followed by Shanghai, Kaohsiung and Ningbo. In addition, while Busan and Kaohsiung were able to maintain their respective shares of capacity received at about 48% and 23%, the end of the period saw Shanghai raising its share of capacity received. As for Ningbo, although the port was able to double its share of ASC connected to the trade, the years after 2002 saw this stagnate at about 12%. The region is an important source of direct as well as feeder cargo for transhipment purposes for the ports and a large number of liners are active. In 2006, there were 51 shipping lines operated on the trade.

The Southeast Asia–Far East trade was ranked the fourth largest trade route after the above-mentioned trades with 74 liner services deployed. Referring to Fig. 7, ASC connected to the ports amounted 11.6 million TEUs in 2006, representing an annual average growth of 11.3% from 5.2 million TEUs in 1995. It had the lowest rate of growth amongst other trade routes. Unlike the major east–west trades which saw Kaohsiung being overtaken by other ports, this trade saw Kaohsiung consistently dominating the shipping scene with the largest share of capacity received, followed by Busan,

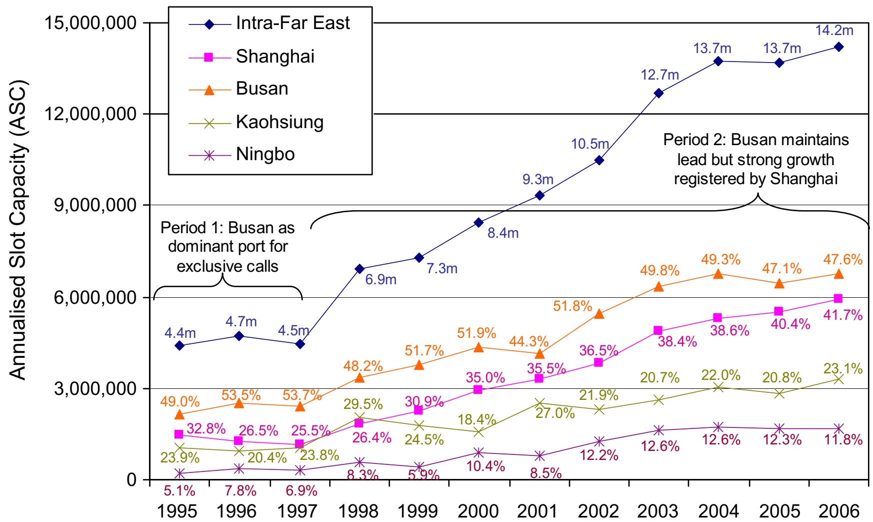

Fig. 6. Development of ASC deployed on the Intra-Far East trade route connected to the selected ports. *Source*: Author's computation.

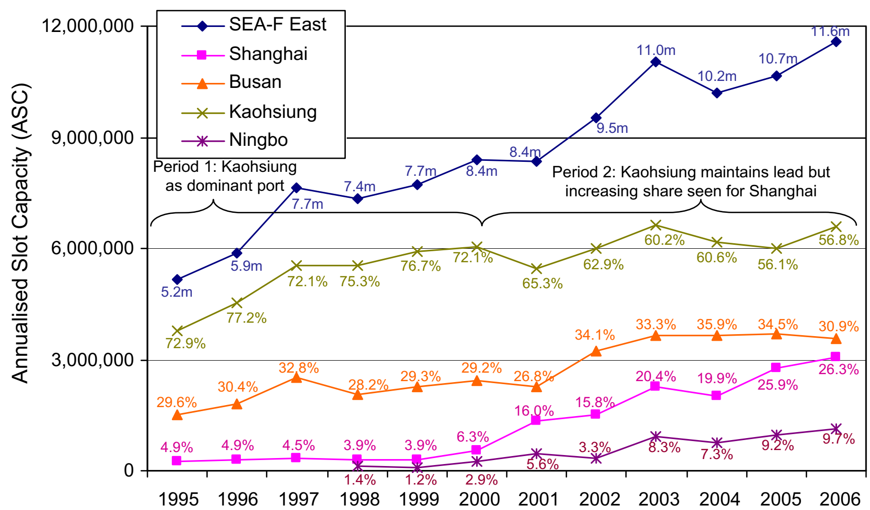

Fig. 7. Development of ASC deployed on the Southeast Asia–Far East trade route connected to the selected ports. *Source*: Author's computation.

Shanghai and Ningbo. Analysis of the shipping services also reveals that majority of the shipping capacity were exclusive calls at Kaohsiung. However, Shanghai registered significant growth rate from year 2000 onwards.

5.3. Further discussion on inter-port dynamics in supply chain systems

Overall empirical evidence from analysing inter-port dynamics among the selected container ports in East Asia revealed Shanghai and Ningbo possessing enhanced supply chain capability. As an integral node in the supply chain, it is important for a port to offer cost-efficient and high-value services to port users. Shippers in the supply chain can benefit from improved connectivity and a larger choice of shipping lines to choose from. Economies of scale and scope generated from higher traffic volumes could also lead to lower cost per TEU handled for both shippers and shipping lines. This is especially important for global shippers who can benefit from a port which is well connected to global supply chains. Shanghai and Ningbo, in particular the former, are increasingly favourable ports of call serving increasing number of regions and supply chains. The performance of the two ports was most impressive in Europe–Far East trade where the shipping capacity called at the ports grew unprecedentedly and surpassed both Busan and Kaohsiung. Yangtze River Delta is indeed a huge industrial and logistics base which can grow the two international ports – Shanghai and Ningbo.

Nevertheless, Port of Kaohsiung's development is rather negative reflected by its decreasing market share in most of the major trade routes except the Intra-Far East trade. Notably, Kaohsiung saw its declining status in the mainline international trades, hence its connectivity to global supply chains. For instance, based on our computation, Maersk, Sea Land and K Line hubbed most of their Transpacific services at Kaohsiung prior to 1998. Among the four ports, Maersk called exclusively at Kaohsiung with 800,000 TEU slot capacity connected in 1995. However, in 2006 Maersk remained only three services with 900,000 TEU called at Kaohsiung, while having six services with 1.3 million TEU called at Shanghai and five services with 1.2 million TEU called at Busan. Lower frequency of shipping services and number of international ports directly connected to Kaohsiung reduce its attractiveness as a transhipment hub. Tongzon (2009) identified that frequency of ship visits is particularly important from shippers' perspective because it influences transit time. Where cargo volumes justify, shipping lines will initiate direct calls at a port. Where the network economies justify a port to be served via feeder services rather mainline calls, shipping lines will not hesitate to do so as well. The gravity of manufacturing has shifted to mainland China and foreign direct investment involves companies of various sizes from countries that include Taiwanese firms. The paper provided evidence that economies afforded by direct calls at mainland ports of Shanghai and Ningbo have seen more shipping lines doing so.

According to the classification of ASC connected, the beginning of the study period witnessed most of the changes in shipping capacity affected to be exclusive calls among one of the four ports. These occurred in the form of attracting shipping lines to initiate calls at their respective terminals. This was especially prevalent for the Transpacific and Europe–Far East trades where ASC deployed by shipping lines was generally initiated at Kaohsiung and/or Busan. But a major portion of the changes in ASC deployed was parallel calls for the major east–west trade routes in 2006. Specifically, the largest amount of parallel calls was uncovered between the port pairs of Shanghai and Busan, Shanghai and Ningbo, and Busan and Kaohsiung. This also resulted in most of the shipping capacity employed on the trades becoming non-exclusive and involved calls at two or more of the four ports.

The results of inter-port dynamics among the container ports of Shanghai, Busan, Kaohsiung and Ningbo are summarised in Table 2. The table shows the accumulative change in ASC from 1995 to 2006 and decomposes their call nature. Over half of the changes in ASC deployed on major east–west trade routes were parallel calls whereas most of the changes in ASC deployed within the region (i.e. within the Far East and between the Far East and Southeast Asia) tended to be more competitive. Results also show that changes in ASC deployed affected mainly Shanghai and Busan, Busan and Kaohsiung, and Shanghai and Ningbo. By comparison, there were relatively few changes in capacity which affected Shanghai and Kaohsiung, Busan and Ningbo, and Kaohsiung and Ningbo. However, the relationship between Busan and Kaohsiung also involved significant amount of changes in shipping capacity that were exclusive calls.

Therefore, port planners, terminal operators and carriers which focus on the competition aspect of inter-port relationships would be missing out on opportunities that could be capitalised through exploitation of complementary relationships that exist among the selected ports. This is significant given the fact that relationships among the four container ports had evolved from a largely competitive to a more complementary dimension from liner network's perspective. Unlike the initial period where container traffic was generated mostly by hinterlands that were served by Busan and Kaohsiung, proliferation of economic development to other parts of East Asia resulted in many regions becoming important centres for container-handling activity as well. Geographical expanse of the region also suggests that it is practically impossible for one port to serve the entire area in a commercially and operationally satisfactory manner. Numerous supply chains crisscrossing inside and through the region necessitate the ports' facilitation in trade and distribution. Thus, this development would present an immense amount of inter-container port complementarity for industry players to benefit from. This point is demonstrated by the fact that a number of container terminal operators was found to be present in at least two of the four selected ports as shown in Table 3. These entities included Hutchison Port Holdings (present in Shanghai, Busan and Ningbo), COSCO Pacific (Shanghai and Ningbo), APM Terminals (Shanghai and Kaohsiung), Evergreen (Busan, Kaohsiung and Ningbo) and China Merchants (Shanghai and Ningbo). This suggests the presence of a significant amount of inter-port dynamics where terminal operators in the ports actively sought to position themselves as important nodes in supply chains that connect between East Asia and major markets in other parts of the world. Complementarity can be commercially realised as a terminal operator can offer a package for shipping lines to call at its portfolio of terminals.

Fig. 8 illustrates a simplified global network of container ports and supply chain systems. Expanding international markets and improving landside transportation and logistics result in hinterlands that increasingly overlap. As a result, inter-port relationships

Table 2
Findings on inter-port dynamics among the four ports in East Asia, 1995–2006 (in TEUs). *Source*: Author's computation.

	Parallel calls (%)	Exclusive calls (%)	Accumulative change in ASC
Transpacific			
Shanghai	65.1	34.9	52,112,000
Busan	63.2	36.8	67,651,000
Kaohsiung	44.7	55.3	51,129,200
Ningbo	57.1	42.9	31,241,400
Overall	**58.1**	**41.9**	**202,133,600**
Europe–Far East			
Shanghai	77.6	22.4	26,078,400
Busan	58.3	41.7	35,561,200
Kaohsiung	60.6	39.4	37,896,400
Ningbo	55.8	44.2	24,135,200
Overall	**62.6**	**37.4**	**123,671,200**
Intra-Far East			
Shanghai	45.4	54.6	17,775,000
Busan	30.8	69.2	20,132,000
Kaohsiung	33.4	66.6	8628,000
Ningbo	66.3	33.7	8573,000
Overall	**41.4**	**58.6**	**55,108,000**
Southeast Asia–Far East			
Shanghai	43.8	56.2	9102,200
Busan	35.2	64.8	11,416,480
Kaohsiung	20.3	79.7	14,128,200
Ningbo	79.8	20.2	5067,600
Overall	**37.6**	**62.4**	**39,714,480**

Table 3
Container terminal operators in Shanghai, Busan, Kaohsiung and Ningbo (2007). *Source*: Compiled from ports' and terminal operators' annual report and website.

Port	Terminal operators	Container throughput (TEUs)	Market share (%)
Shanghai	**SIPG (26.5% owned by China Merchants)** **Hutchison Port Holdings** **COSCO Pacific** **APM Terminals** China Shipping	26,150,000	44.3
Busan	Korea Container Terminal Authority Hanjin Shipping **Hutchison Port Holdings** DP World **Evergreen** Various Korean companies	13,270,000	22.5
Kaohsiung	APL Yangming **Evergreen** **APM Terminals** NYK OOCL Wan Hai	10,257,000	17.4
Ningbo	Ningbo Port Group **Hutchison Port Holdings** **COSCO Pacific** **China Merchants Group** **Evergreen** OOCL MSC	9360,000	15.9
Total		59,037,000	100.0

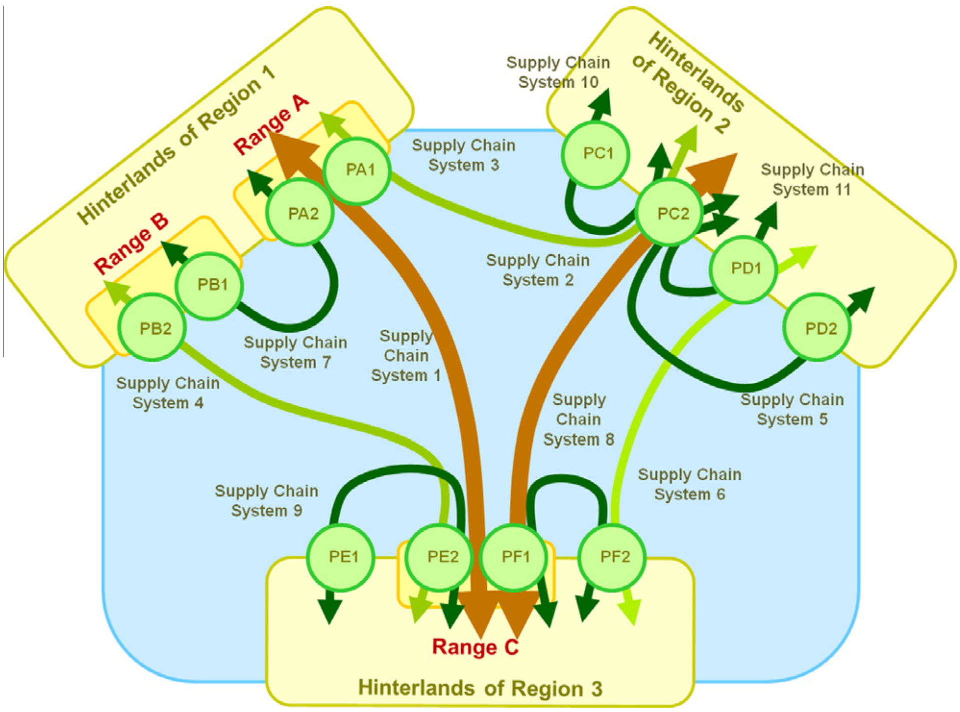

Fig. 8. Conceptualisation of inter-port relationships in supply chain systems.

can occur at the range level as supply chain systems have the choice of utilizing the services of various ports located within the range (e.g. ports in Ranges A and C in Supply Chain System 1) or even between ranges (e.g. ports in Ranges A–C in Supply Chain Systems 1 and 4). Apart from inter-port, inter-range and intra-range relationships, supply chain systems can also exist in the form of hub-and-spoke, inter-lining and relay connections between hinterlands located in the various container port ranges. The example for hub-and-spoke connection can be illustrated in the form of a hub at P_{C2} with spokes connecting to P_{C1}, P_{D1} and P_{D2} and even P_{A1} whereas interlining connections can be shown by services attempting to connect between P_{A2} and P_{C2} having a choice to perform interlining at P_{E2} or P_{F1} in range C. As for relay connections, the example can be found from services connecting P_{B2} to P_{C2} having a choice of performing relay transhipment at either P_{E2} or P_{F1}.

The broad spectrum of players involved can result in competition occurring in the form of alliances or cooperative arrangements between participants in the same supply chain system(s) against those of other supply chain system(s). There would be enormous amount of opportunities available to container ports to capitalise on competitive and complementary relationships with respect to other logistics service providers and their respective sources of competitive advantages and disadvantages in the paradigm of supply chain systems.

6. Policy and research implications and recommendations

The perspective of analysing ports by ranges and by supply chain systems can generate new insights for policy and research. The study shows that analyses of inter-port relationships should include both competitive and complementary aspects. By distinguishing between the effects of exclusive calls and parallel calls as a result of changes in shipping capacity, we are able to unveil port call developments and nature of interplay among the major container-handling regions in the world. By empirical investigation, it is shown that the decision by liner shipping services to call at a port can be influenced by the joint competitive offering of a group of ports instead of a single entity. The extent of complementary relationships can even exceed the amount of shipping capacity involved in port competition in some cases. As the notion of complementarity suggests that container ports are related to each other through the network of shipping services in a mutually supporting manner, policies and decisions implemented in one port would have resulting implications for other ports which are complemented by the network of services linked to the ports in question. For instance, investments undertaken to improve a port's accessibility, such as upgrading of factor conditions, could boost the demand attractiveness of the port and have resounding impact on other ports which are complemented by the port. Transmission of these effects throughout the network further suggests that economic contribution of a port would be underestimated if the assessment was restricted to the locality.

Focusing merely on combating inter-container port competition would be insufficient to realise the overall scene. The study finds that inter-container port complementarity accounted for a significant share of changes to shipping capacity affected in the four major ports in East Asia. Hence, we recommend policy and decision makers to pay more attention to implications offered from inter-container port complementarity in supply chain systems in order to advance the competitive position of their respective ports. Port operators and authorities concerned with port planning and regional development should be proactive in identifying and engaging relevant stakeholders to address potential opportunities that may arise. For example, a municipal government can coordinate the efforts with the aim to increase the collective competitive advantage of the ports in the range. This also draws reference for other ports such as Japanese ports as they announced the plan to restore their hub port status. However, the research also shows that the symbiotic nature of inter-port relationships is not constant as container shipping lines periodically restructure their networks to adjust to the demands from the market. Therefore, policy makers should keep themselves abreast of any new inter-port dynamics and craft decisions accordingly.

The research also shows that analyses of relationships between container ports should not be performed at an aggregated level.

With various supply chains served by each port involving different decision makers, regions, routes, cargoes and shipping lines connected to, it is unlikely for a port to be competing with another port on the whole spectrum of variables and sectors. Similarly, it is impossible for complementary relationships between two ports to extend to all their markets served. Slot capacity analysis performed in the study demonstrates that quantification of inter-port dynamics revealing the specific details can be conducted. Hence, we hope to draw decision makers' and researchers' attention to the need to identify the extensity and intensity of such relationships in order to formulate decisions with higher exactitude.

It is important that policy makers should understand and be aware of the distinctive characteristics of the business, particularly so if the policies are intended for that sector. This premise applies to all regulatory bodies including port authorities, competition commissions, industry promotion organisations, government ministries and local municipalities among others. The reason for so being is attributed to the greater extent and wider influence of the economic, political and social effects of their policies and welfare consequences on society as a whole. This paper reveals the complexities involved in the container shipping and port industry in supply chain systems. Thus, better understanding of the industry could yield more effective policy responses and enhanced knowledge of the outcomes while at the same time, minimise unintended consequences as a result of greater precision in the application of policy instruments on specific sectors, trade routes, shipping lines, cargoes, shippers and even port entities among other target groups.

The paper also adds value to the literature by demonstrating a new method, slot capacity analysis, to study ports as elements in supply chains. The method is a versatile tool to specify ports' connectivity and inter-port relationships in supply chains. Empirical research in this research theme has been quite limited and mainly employed opinion survey instruments. This paper is the major empirical work in the literature so far to use factual secondary data for analysis. Ships and shipping companies are direct users of ports. Ships' calling pattern is a revealed preference embedding ports' relative performance in all the factors determining port choice. Hence, ships' action (calling pattern) reveals pricing, productivity, terminal capacity, port infrastructure and superstructure, quality, cargo demand and other factors. For example, due to increasing ship size, there is a reconfiguration of shipping routes and a modification in ports of call. Shanghai receiving more ASC reflects its capability of handling larger ships. To view from another angle, if Yangshan were not built and Shanghai were to continue with shallow water depth, liners in particular mainline vessels would be deterred by such unfavourable port condition and the ASC connected to the port would be restricted. The methodology is a powerful tool for comprehensive and objective analysis, offering a new perspective to other data analysis such as cargo throughput and port charges. In summary, analysing ASC can quantify ship's calling pattern and port's connectivity in specific details with changes across the years concerned, e.g. trade routes covered, shipping lines called, parallel or exclusive calls. There is no other similar method that can provide such specific details. These fresh research elements can deepen our understanding on inter-port dynamics and facilitate future research in the field.

7. Conclusions

The paper has presented a detailed examination on the calling patterns of liner shipping services in order to understand the dynamics of liner shipping network and port connectivity. Empirical analyses were conducted on the ports of Shanghai, Busan, Kaohsiung and Ningbo in East Asia. Particular attention was drawn on discussing the dynamics in the context of supply chain systems. The research findings presented were based primarily on evidences provided by container shipping services that called at the selected ports and container throughput handled at these ports between 1995 and 2006. While the merits of this approach have been discussed, we will analyse the study's limitation and suggest some future research areas.

A limitation of the research is that it has adopted a broad definition of complementarity in port calls where two ports were noted to be complementary from liner network's perspective if container shipping services were initiated to call jointly at or removed from both ports. However, the narrow definition of complementarity would define both ports to be complementary only if initiation of calls by ASC at one port requires ASC to call at the other port as well. Nevertheless, such information is unlikely to be available on public domain as they require insight into the planning mechanism of shipping lines. Hence, the best available option was to observe actual ASC deployed and changes to such capacity. Other analysis on, for instance, container throughput handled by the ports, investment strategy of terminal operators and container shipping lines will supplement and enrich the research. Moreover, it would be useful to account for the network structures of the selected ports and order of port call in order to yield greater clarity on the competitive and complementary relationships embedded within the supply chains. Also, examination of inter-port relationships for East Asia could also account for other ports that are also competing with the selected ports for transhipment traffic and these could include those that are located beyond the Yangtze River Delta. These gaps present potential areas for further studies.

The period of analysis covered 12 years from 1995 to 2006. Although the paper accounted for the situation prior to the formation of shipping alliances to the series of acquisitions that involved major container shipping lines which led to significant changes to shipping service schedules that became apparent only in 2006, future research could examine the effects of the economic downturn started in 2008 on relationships between container ports as shipping lines adjust their fleet deployment and service arrangements to counter the influence of the slowdown in container trade. Furthermore, slot capacity analysis is a resourceful technique that can be employed for other port studies with different focus according to the research questions concerned. We hope to stimulate more research related to maritime transport, which is the dominant mode of transport in international trade and has a significant impact on regional development and global economy as a whole.

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