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Master Degree Project in Logistics and Transport Management

Cooperation Vs. Non-Cooperation between Ports and Shipping Lines: a Game Theory Approach

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Abstract

In response to fierce competition of container cargo transportation markets, cooperation has become the mainstream of this era. Consolidation of shipping routes, globalization of shipping lines and cooperation of port operators have emerged. This paper adopts a game theory approach to modelling consolidation of shipping lines and ports, and establishes a two-stage game scenario with two ports and multiple shipping lines. In the first stage, shipping lines and ports decide their cooperative strategies based on their prediction. The second stage is modelled as a static game with the coalition and the others that have not joined the coalition. Numerical analysis is conducted to obtain the main properties of some key parameters as well as the best choices of shipping lines and ports. The results show that the cooperation strategy of shipping lines strongly depends on the supply and demand situation of ships. The port which collaborates with shipping lines will have a significant decrease in port charges, which creates an advantage of gaining more port calls and demand, but it will have a limited effect on the charge of the other port. The cooperation may result in a loss to the port, thus reallocation of profit is needed to maintain the coalition.

Key words: cooperation, ports, shipping lines, game theory, coalition

Tables

Figures

Table of Contents

1. Introduction

1.1. Background description

With the development of the global economy, international trade has become an important factor for the economic advancement of East Asia. As a key element of the international trade chain, the shipping industry carries over 90 percent of the world's trade transportation (Benamara et al., 2010).

As two important elements in the shipping industry, shipping lines and ports' management performance have a great impact on both the regional economic propensity of development and competition among the industry. However, after the economic crisis in 2008, the global shipping industry slumped to a trough. Both ports and shipping lines are facing the challenges brought by the imbalance between sea transport supply and demand which, as a consequence, makes competition throughout the shipping industry fiercer.

Following the financial crisis, the ship liner industry has deep seated issues of overcapacity. This is due to new vessels purchased before the downturn flooding the market. As such, rates on the main route between Asia and northern Europe have risen to unprofitable levels. In order to regain profitability, consolidation of shipping routes and globalization of shipping lines has become common practice. The three shipping firms, "P3" alliance between Maersk, MSC and CMA CGM, have taken steps to commit their fleet into a joint operation which will operate the vessels from a centre located in London by 2014. Furthermore, in order to reduce costs, p3 networks have reached an agreement for consolidation of three trade routes: Asia-Europe, trans-Pacific and trans-Atlantic. As a result, the shipping lines, which previously operated the majority of their fleet only partly laden, will operate larger vessels which are more fuel efficient and fully loaded (REUTERS, 2014).

The consolidation of shipping lines has resulted in substantial changes to the shipping industry. As container shipping lines shift to larger vessels, the shipping route structure becomes a hub-and-spoke structure. This trend has brought forward higher requirements of the infrastructure and nature condition of ports. At the same time, it has exacerbated the veracity of regional port competition, as only one hub port can exist in a region and other ports will degenerate into the feeder ports.

In order to maintain a competitive edge, ports have to improve their port facilities and management level. Meanwhile, cooperation has become another important means of enhancing port competitiveness. This manifests as port cooperation and the cooperation between shipping lines and ports. The competition to become the shipping hub port is so intense that main ports often struggle to form a partnership in a region, thus the predominant form of cooperation among ports is between large port and small feeder ports. However, the cooperation between shipping lines and ports has gradually become a popular issue in recent years. The relationship between shipping lines and ports is special. Management decisions made by a large shipping line or a gateway port can often change a region's shipping industry stage, and, sharing a vast portion of the total revenue in one supply chain, ports and shipping lines can become mutually beneficial partners. Redesigning management strategies and profit shares vertically in a supply chain provides the whole shipping industry with a new option to achieve change.

In 2001 the Strait of Malacca, Maersk Line, who has been in cooperation with the Port of Singapore Authority (PSA) for several years, planned to divert its containers to the Port of Malaysia (PTP). This kind of cooperation, known as port investment, increased PTP's tranships frequency sharply and enabled PTP to attract a large amount of transport demand. As a result of this, PTP immediately became an important container port ranking 26th in the world. Indeed, PTP was still ranked 108th place in the world one year ago. Meanwhile Maersk Line started enjoying the priority obtained in PTP and receiving a proportion from PTP's port operation revenue as a stable income. A few months later, another shipping line relocated its containers to PTP. However, this "win-win" cooperation did not develop well. Due to the limited capacity, PTP terminals soon became overcrowded. Given the poor tranship service that they could provide; PTP soon faced a substantial challenge in operating effectively due to the volume of containers. This case effectively displays the fact that there are several factors which must be taken into account when assessing a port's performance. It is important to achieve a more developed understanding of how these factors affect the cooperation between ports and shipping lines. However, theoretical research on this subject is not enough; cooperation between ports and shipping lines must also be investigated, alongside numerous other influential factors.

In 2014, P3 network, the alliance of the world's three largest shipping lines will be formed. The shipping industry is not the only industry concerned with this consolidation. The stevedoring industry has also expressed its concern, as the coalition's strategy is likely to result in the relocation of main port of Northeast Asia from Busan to Shanghai port and Ningbo port (The Korea Economic Daily, 2014). Facing this changing environment, other market players are also adjusting themselves to the challenge. Port authorities are allowing shipping lines to acquire a substantive and long term financial stake within ports. The exacerbation of this trend may result in a decline of the 'footloose' nature of shipping lines and result in stable, and potentially more economically beneficial, ties.

As key nodes in the international trade chain, ports and shipping lines are facing continuously growing difficulties. On one hand, they are under pressure caused by their superior cooperating partners in the supply chain, resulting in a shrinking profit. On the other hand, external requirements to become sustainable have consistently provided challenges to the industry. The cooperation of shipping lines and ports not only provide funds for ports to improve transhipment service level, but also enable shipping lines to gain a stable income from port operation. In addition, this decreases operation risk, thus offering a new means for ports and shipping lines to increase their profits.

Though this paper aims to address these wider issues, an application of Shanghai and Busan ports will also be conducted. By creating a model, the cooperation between ports and shipping lines will be analyzed, followed by an analysis of the effect of different variables. The aim of this paper is to put forward theoretical and practical advices for this issue.

In performing this research, a model which describes the cooperation is needed, alongside necessary data collection and analysis. Section 2 will provide a theoretical framework of this issue. Section 3 presents the methodology. A modelling part is conducted in Section 4 through an explanation of the model and an illustration of how it functions. Section 5 analyzes and tests the variables in the model, displaying the effect of different factors on the coalitions. Section 6 presents an application of the case of Shanghai and Busan ports with the data collected. In the final section, a conclusion will be stated.

1.2. Research purpose

In order to obtain more understandings of the cooperation between ports and shipping lines, By doing this research, the authors are going to make a deep investigation of relationship among shippers, shipping lines and ports in a straightforward way. To investigate the influence of different factors on the cooperation between ports and shipping lines is also the aim of this purpose.

Shippers' surplus

Shippers' surplus is the difference between the highest price a shipper is willing to pay and the actual price he does pay (Mankiw, 2014). There are two main factors which shippers take into account when bargaining a price: total logistics costs and service quality (Ben—Akiva, Bolduc, and Park, 2013). The service involves inland transport service, port service and maritime transport service. Logistics costs contain direct cost, such as transport cost, transshppiment fee and inventory cost, and indirect costs include time cost and unreliability cost. A shippers' choice of port is based on these considerations, in an attempt to maximize their surplus.

Shipping lines' cost and revenue

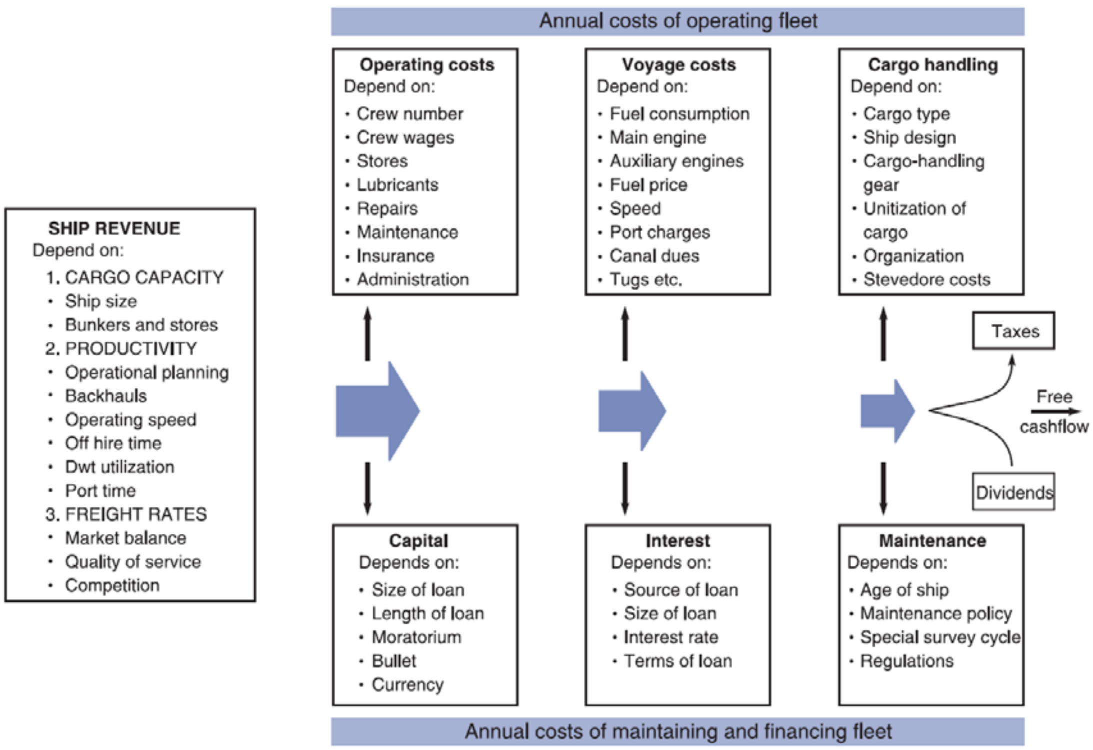


Figure 1 Shipping line's revenue and cost

Source: Maritime Economics (Martin, 2009, p. 220)

According to the Figure 1, three variables are essential for shipping lines' survival. The first variable is ship revenue obtained from operating or chartering. The second variable is the cost incurred by operating, maintaining and financing fleet. The third variable is the method of financing the business (Martin, 2009, p. 216).

In consideration of the first variable, it can be observed that the shipping lines' revenue comes mainly from transport income. However, the income depends on multiple factors, including the condition of ships, the operation management level, the market balance and level of competition.

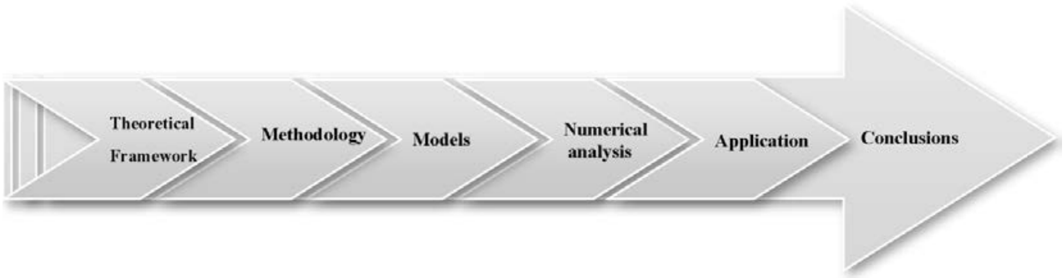
The cost of maintaining ships is also crucial to the survival of shipping lines. This cost can be classified it into six categories: operating cost, voyage cost, cargo cost, capital cost, interest cost and maintenance cost.

In accordance with the ship revenue and cost, it can be observed that shipping lines can pursue more profit by adopting several techniques. These include: equipping larger ships to increase the cargo capacity to achieve economies of scale; reducing the number of port calls to decrease the steaming time and forming an alliance to consolidate shipping routes; thus limiting extensive competition. The adoption of such techniques provide a clear picture as to the developing trends within the shipping industry

1.3. Delimitations

This thesis is designed to analyze the rationality of the cooperation between shipping lines and ports. The cooperation of two major ports and N big shipping lines in a region is discussed; the case of more than three ports is not investigated. Furthermore, this paper investigates the strategies of shipping lines and ports from the financial perspective, but ignoring the social impact, such as environment. In addition, there are many types of cooperation between shipping lines and ports, such as Port investment, Business cooperation. In this thesis, Full Cooperation between shipping lines and ports is discussed in which all the alliance members aim to maximize the coalition's profits.

1.4. Outline



Theoretical framework and literature review

This section outlines the theories and concepts that relevant with the shipping industry. A comprehensive literature review is conducted, such as introduction of shipping industry, factors influencing ports' competitiveness, cooperation in shipping industry and competition of ports.

Methodology

This section elaborates the research approach, research design, method, data collection and quality of research.

Models

In this section, game theory models are conducted to analyze the influence of cooperation between shipping lines and ports on the shipping market, and several lemmas are proved to support the results obtained.

Numerical analysis

In this section, since the results cannot be presented in a closed form, a numerical analysis is conducted to illustrate the results of the model.

Application of Busan and Shanghai ports

In this section, an application of the case of Busan and Shanghai ports is conducted. According to the model, several advices are given to both ports.

Conclusion

This section presents the managerial insights and findings from this study. Furthermore, a future research is provided.

2. Theoretical framework and literature review

2.1. Introduction of shipping industry

2.1.1. Port

A port can be generally defined as the "*interface linking marine and inland transportation*" (Polis and Hurd, 1996). Nowadays, a port acts as a link for logistics, information, production, living, financial, international trade and a base for economic development of hinterland (Frankel, 1987). Given the fact that the large proportion of international trade is conducted in this way, the port and shipping industry have become extremely critical in the economic well-being of numerous regions (Langen, 2007).

However, the different terms of "Port", "Port Authority" and "Terminal" have to be clarified. As defined by Martin (2009), a port is "*a geographical area where ships are brought to load and discharge cargos*"; a port authority is the organization who is responsible for the maritime service; while a terminal is a group of berths devoted to handling a particular type of ship. A port is consisted of a number of terminals (ibid).

The functions of ports

Considered as a key element in a value-driven chain, a port usually has a variety of functions.

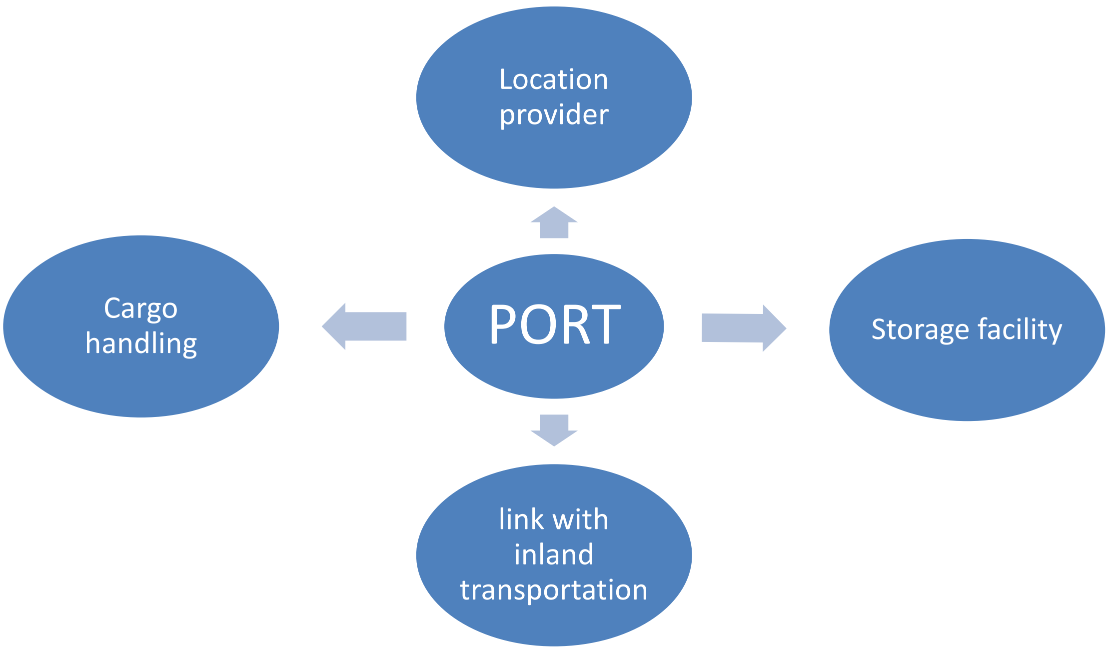


Figure 2 The functions of a port

Source:(Martin, 2009)

Top ports in the world

Not only can a port promote a region's economic well-being, but also the condition of a port supply chain acts as a reflection of the status of regional economy. Due to the rapid economic growth in Asia in recent years, large Asian ports take every position in the world's top 10 ports in 2012. Ranked as the number one port in the world, Shanghai handled 32.5 million TEU of cargos in 2012; leading Singapore and Hong Kong. The first three ports of Europe are

Rotterdam from Netherlands, Hamburg from Germany and Antwerp from Belgium, which rank 11, 14 and 15 respectively. Los Angeles, Long beach and New York are the first three ports in US. (Table 1)

Table 1 Top ports in the world

2012	2011	Port	Country	Million TEU 2012	Million TEU 2011
1	1	Shanghai	China	32.5	31.7
2	2	Singapore	Singapore	31.6	29.9
3	3	Hong Kong	China	23.1	24.4
4	4	Shenzhen	China	22.9	22.6
5	5	Busan	South Korea	17	16.2
6	6	Ningbo	China	15.7	14.5
7	7	Guangzhou	China	14.7	14.3
8	8	Qingdao	China	14.5	13
9	9	Dubai	UAE	13.3	13
10	11	Tianjin	China	12.3	11.6
11	10	Rotterdam	Netherlands	11.9	11.9
14	14	Hamburg	Germany	8.9	9
15	15	Antwerp	Belgium	8.6	8.7
16	16	Los Angeles	US	8.1	7.9
22	20	Long Beach	US	6	6.1
24	24	New York	US	5.8	5.5

Source:(Happen, 2013)

2.1.2. Shipper

Shipper, who is also known as cargo owner, is another important player in shipping industry. According to the relation with shipping lines, Tongzon (2008) distinguishes shippers into two categories. The first group is those who are in a long-term relationship with a shipping line. Hence they have a fixed partner to cooperate with in a long term. Comparing to this, the second one is independent shippers, who always have to make a choice through which route to transport their cargos.

The commodities transported by shippers include energy resource or products, metal products, agricultural and forestry products and other commodities (Martin, 2009).

2.1.3. Freight forwarder

Freight forwarder is defined as "*an international trade specialist who can provide a variety of functions to facilitate the movement of cross-border shipments*" (Murphy and Daley, 2001). Freight forwarders are usually responsible for complex documental work in cross-border trade. They also make key decisions, such as choosing a route to transport cargos for shippers. Owing to the expertise which they have acquired, freight forwarders are usually utilized by shippers and shipping lines (Lambert and Lambert, 1998).

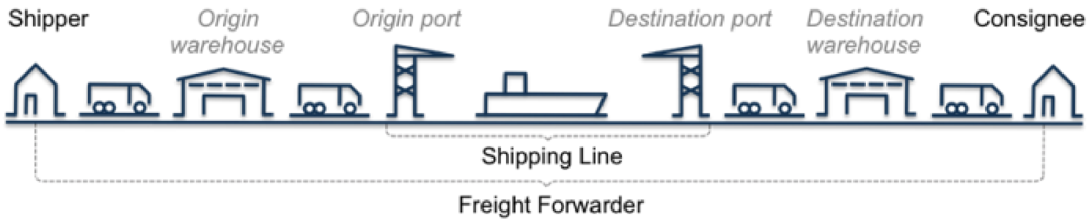


Figure 3 Division of freight forwarders

Source (Transporteca, 2014)

2.1.4. Shipping line

Shipping lines, which provide liner shipping service to the users, play a prominent role in facilitating global trade. They not only enable the cross-region transport of the cargos, but also are involved in the marketing and commercial aspects in international trade. Here lists the top shipping lines in the world.

Table 2 Top shipping lines in the world

Rank	Operator	TEU	Ships	Share
1	APM-Maersk	2,681,027	573	14.8%
2	Mediterranean Shg Co	2,431,235	489	13.4%
3	CMA CGM Group	1,522,779	424	8.4%
4	Evergreen Line	880,344	197	4.9%
5	COSCO Container L.	781,392	157	4.3%
6	Hapag-Lloyd	773,527	156	4.3%
7	APL	626,908	115	3.5%
8	CSCL	615,572	132	3.5%
9	Hanjin Shipping	597,881	102	3.3%
10	MOL	593,243	116	3.3%
11	Hamburg Süd Group	490,101	109	2.7%
12	NYK Line	478,896	106	2.6%
13	OOCL	477,579	91	2.6%
14	Yang Ming Marine Transport Corp.	390,654	88	2.2%
15	Hyundai M.M.	374,858	62	2.1%
16	PIL (Pacific Int. Line)	363,447	166	2.0%
17	K Line	350,562	67	1.9%
18	Zim	326,420	83	1.8%
19	UASC	282,406	50	1.6%
20	CSAV Group	234,930	48	1.3%

Source: (Alphaliner, 2014)

Given the globalization of world's trade, shipping lines in the world are getting bigger and fewer. As shown in Figure 4, the market share of the top 20 shipping lines consists 84.5% of the total volume in the world.

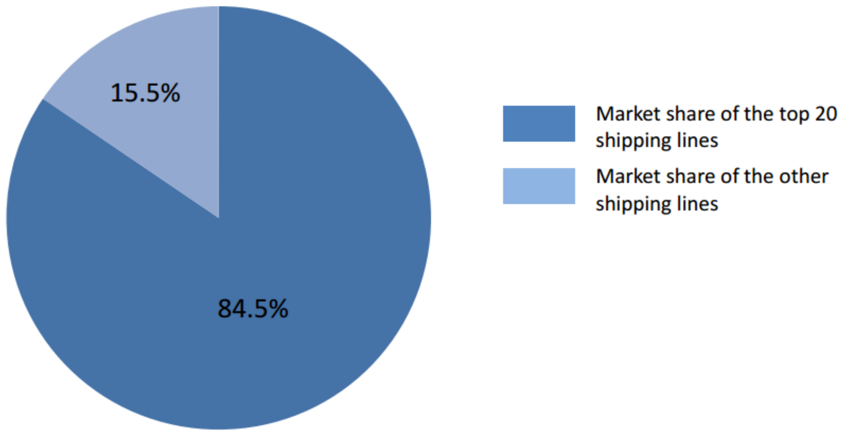


Figure 4 Market share of shipping lines

2.2. Factors influencing ports' competitiveness

2.2.1. Port efficiency

Port efficiency can be perceived as the speed and reliability of port service (J. L. Tongzon, 2009). Researchers often use different indicators to measure the efficiency of a port. Tongzon and Ganesalingam (1994) separate the indicators of port efficiency into two categories: the first set is operational efficiency measures which deal with capital and labour productivity as well as asset utilization rate. The second set is customer-oriented measures including ship's waiting time, direct charges, minimization of delays in inland transport and reliability. Wiegmans et al. (2008) use port turnaround time, terminal productivity, cost efficiency and port operating hours as the indicators of port efficiency.

Though researchers have different opinions about the indicators of port efficiency, it is generally agreed that efficiency is one of the most important factors influencing ports' competitiveness.

In fast-paced industries, products must reach their destined market on time (J. L. Tongzon, 2009). The efficiency of a supply chain is always dictated by the weakest link (or node) (Yuen et al, 2012). The port, which acts as a link in intermodal transportation network, connects the foreland, where containers are transported by shipping lines, and hinterland, where cargos have to be delivered by rail or trucks (Wan et al, 2013). As such, the efficiency of ports is of vital importance and are frequently challenged (Gardiner, 1997). Haynes et al. (1997) believes that efficiency gained by ports can potentially results in economic benefits to both manufacturers and customers. Contrarily, Tongzon (2009) believes that inefficiency of a port results in higher costs for the port users. The longer a ship stays in a berth, the higher costs it has to pay. Occasionally, the charges are transferred to the shippers. According to Langen (2007), shippers are even willing to choose a more expensive port with high efficiency and lower risk of delay.

Port efficiency not only concerns the costs that users must pay, but also has a direct correlation to the potential profit earnings. High efficiency can shorten the turnaround time of ships, which means more cargos can be transported and thus, a higher profit be obtained. Wiegmans et al. (2008) have conducted research into deep-sea container transport. They find that congestion in a port results inevitably in unreliability and delays and that deep-sea container carriers are inclined to choose a port with low congestion level.

Additionally, some indirect costs are also considered by port users. These include the loss of market share, loss of customer confidence, loss of commercial opportunities and so on (J. L. Tongzon, 1995).

2.2.2. Hinterland conditions

Hinterland, defined as a "*continental area of origin and destination of traffic flow through a port*" (Van Klink and van Den Berg, 1998), is another important character of ports, especially for gateway seaports. Gateway ports, serving as the origin of export containers and the destination of import containers (Luo and Grigalunas, 2002), is strongly influenced by the status of regional economic development. In 2010, the top five container ports in the world were all from Asia due to the rapid growth of economy in Asia (C. A. Yuen et al., 2012). As an example, the hinterland of Shanghai Port is mainly Yangtze River Delta, China (Veenstra and Notteboom, 2011). The strong cargo transport demand in the area causes 32.5 million TEU of port throughput in 2012, resulting in its status as the top container port in the world. Almost all shipping lines allocate ships in the port of Shanghai. (See Table 1)

Hinterland conditions can influence a port's competitiveness from two perspectives. The first one is the coverage of hinterland. The second one is hinterland connection conditions.

Hinterland coverage

As explained above, huge cargo transportation demand can help increase a port's attractiveness for shipping lines, consequently raising the shipping service level at a port. However it is complicated to evaluate the coverage of a port's hinterland.

Langen (2007) differentiates hinterlands into captive hinterlands and contestable hinterlands. For captive hinterlands, the port usually has a substantial competitive advantage in the region, attributed to the low generalized costs. As a result, the port handles the majority of the cargos transported in the area. However, because of the increase of port competition, this particular kind of hinterland is diminishing around the world (Haralambides, 2002). Another kind of hinterlands is contestable hinterlands, where there is no single port with clear costs advantage over other ports in the region (Langen, 2007). For the ports which serve a contestable hinterland, the competition is fierce. Cargos can be shifted between ports. Hence these ports have to face the risk of losing market share constantly. Because independent shippers often choose a port from the perspective of inter-modal transportation Tongzon (2009). A port can attain a majority of the share of contestable hinterland with the competitive advantage of the entire supply chain. Anderson et al. (2008) also believe it is the route that be chosen by shippers to transport cargos and when making a decision, the costs of the entire transport route has to be considered and be compared to others.

Impact of hinterland connections on ports' competitiveness

Wan and Zhang (2013) and Wan et al. (2013) believe that hinterland connection or inland access is considered as one of the most influential factors of seaport competition. Wiegmans et al. (2008) argue that a port's hinterland connection is a critical success criterion for deep-sea container carriers. Yuen et al. (2012) also prove that “hinterland connections” is an important factor for shippers and carriers as well as freight forwarders. However, more researches have proven that it is particularly critical from the perspective of freight forwarders and shippers (Wan et al., 2013). Compared to operations of shipping lines having mainly consisted of deliveries of goods between ports, it is mainly freight forwarders’ responsibility to pick up the cargos from the manufacturer and deliver them to the market. So the hinterland connectivity will be of great concern to the freight forwarders (Tongzon and Sawant, 2007). According to Heaver (2006), the bottleneck of inter-modal transportation chain has already shifted from the ship/port interface to the port/ inland interface in most regions of the world. The connectivity of inland transportation will deeply influence the efficiency of the entire port supply chain and thus the port’s competitiveness.

To measure the condition of hinterland connections, road congestion, road capacity and other inland infrastructures are often used as the indicators by researchers (De Borger and De Bruyne, 2011; De Langen, 2007; Wan et al., 2013; A. Yuen et al., 2008). Congestion at urban roads increases fuel costs, cargo travelling time and the possibility of missing schedule; lowering the reliability of commercial truck operations (Wan et al., 2013), and thus causing a strong negative impact on the chance that certain ports will be selected by shippers (Nir et al., 2003). Contrarily, seaports with better hinterland transportation infrastructures have more chance to survive in newly-established trade flow market (Fan et al., 2011). By a research conducted by Wan et al. (2013), it is proved that “*a 1% increase in road congestion delays around the port is associated with a 0.90-2.48% decrease in the port’s container throughput but a 0.62-1.69% increase in the rival port’s throughput*.”

2.2.3. Frequency of ships

The frequency of ships at a port is an important character of ports. Freight forwarders often prefer to choose a port with more shipping lines (De Langen, 2007; Sánchez et al., 2003; Tiwari and ITOH, 2003; C. A. Yuen et al., 2012). Higher frequency of port calls provides greater flexibility to the shippers and freight forwarders, and lower the total transport time (J. L. Tongzon, 2009). Due to the advantages brought by the high frequency of ships at a port, more cargos will be transported via the port. As the amount of cargo increases, the average carrier costs falls and becomes more competitive because of the economy of scale (J. L. Tongzon, 2009). As a result, even more ships will be allocated at the port. So the improvement of frequency of ships cannot be easily completed by a single port operator, but a dynamic process.

2.2.4. Other factors

In addition, there are also some other factors that influence a port’s competitiveness, including location, shipping service, adequate infrastructure, port charge and so on (J. L. Tongzon, 2009).

2.3. The relevant importance of factors

Researchers find for different port users, the relevant importance of each factor is different. Hence big efforts have been paid into the study of the relevant influence of factors. The literature dedicated to this issue can mainly be divided into three parts: port competitiveness from shipper's perspective, port competitiveness from shipping line's perspective and port competitiveness from comprehensive perspective.

2.3.1. **Ports' competitiveness from shippers' perspective**

In order to study the competition for shippers, Nir et al. (2003) take three regions of Taiwan as a case to investigate the shippers' port choice behaviour. The revealed preference theory is applied to build a competitive port choice model. The results indicate that the negative effects on shippers are consistent with container travel time. Shippers are willing to choose the nearest port for saving travel time. However, the frequencies and routes don't have significant influence on shippers' port choice decisions. Furthermore, the time value for port choice will be higher if calculated by the experienced model, compared with that of overall experienced model and competitive model, despite of competition among ports. This means choice decision of future port will affected by the port choice experienced. Other factors such as port facilities, port services, routes and frequencies have no significant effect on port choice behaviour. (ibid)

Unlike other researchers, J. L. Tongzon (2009) divides shippers into three types: the first group shippers are those who have already established long-term relationship with shipping lines. Thus they do not have to choose a port, but leave this decision to the shipping lines. The second type is those who cooperate with freight forwarders, and the third one is those who are independent. In which Tongzon thinks only the last two types of shippers need to make such decision to choose a port. And the independent shippers are often choosing a port from the perspective of inter- modal or carrier selection. Based on this understanding, Tongzon does a survey on freight forwarders in Southeast Asia, finding that the frequency of ships at a port, port efficiency, port location, competitive port charges and quick response to port users' needs are the most important factors for a port to compete for freight forwarders. By asking the respondents, Tongzong finds that port efficiency is ranked in the first position by the sampled freight forwarders, followed by shipping frequency, adequate infrastructure, and location.

2.3.2. **Ports' perspective from shipping lines' perspective**

However, the factors influence port choices are different from shipping lines' perspective. Tongzon and Sawant (2007) use survey and preference valuation method to analyze the main factors of port choice from shipping lines' perspective. Through the method of survey, he finds that the efficiency of port operations is the most important factor. And the following factors are port price, port connectivity, port geographic location, service coverage and cargo size. However, he finds the different results that the port price and the efficiency of port operation are the critical factors through preference valuation method. Anderson et al. (2008) suggests that shipping lines primary concern cargo volume, port handling charges, berth condition, transhipment cargo volume and feeder port connectivity. He further points those trunk lines are more sensitive to port price than feeder lines. For practical, port should treat trunk lines and feeder lines in different approach. Since value-added services and port price are biggest concern of trunk lines, port needs to provide a more comprehensive range of value-added services to trunk line vessels and lower rates as much as possible. At the same time, port has to improve its market scale and optimize the operation environment to attract feeder line ships. Lirn et al. (2004) applies analytic hierarchy process (AHP) method to analyze international shipping lines' preference of port of transhipment. He finds that international shipping lines' biggest concern is port service quality. (C. A. Yuen et al., 2012) analyzes the port choice preference from shippers and forwarders perspective through applies analytic hierarchy process (AHP) method. The conclusions are shipping lines' primary concern is port price and shippers value port position most.

2.3.3. Comprehensive perspective

To study the competitiveness factors from comprehensive perspective:

Chiu (1996) holds that service level, response speed, complexity of port formalities, cargo intact rate and operational standardization of port are the most important factors influence port competitiveness. On the research of port service, Collison (1984) suggests that the customer standby period, on time performance and the response speed of terminal scheduling system are critical factors. However, Willingale (1981) studies the port competitiveness from hinterland aspect, he figures out that the steaming distance, the coverage of hinterland, port facilities and port price are key factors form shippers' choice. Starr (1994) further notes that the port geographical position, transport system of hinterland, port infrastructure and stability of labour force will strongly influence the port competitiveness.

Unlike formal researchers, C. A. Yuen et al. (2012) investigated the port competitiveness from three different perspectives. They divide the users into shipping lines, freight forwarders and shippers. By three groups of face to face interviews and 356 telephone interviews, they summarize eight important factors that impact a container port's competitiveness, including port location, costs at ports, port facility, terminal operations, port information systems, shipping service, hinterland connections and customs and government regulation. From the results of interviews, they also get the relevant importance of each factor to a port's competitiveness. For shipping lines, they find, costs at port is the most important one influencing a port's competitiveness, followed by customs and government regulation. In the case of shippers, however, it is port location which is ranked in the first position. And for freight forwarders, they also consider port location as the most important factor, leading hinterland connections and shipping service. However shipping service is not even taken into shipper's consideration.

2.4. Cooperation in shipping industry

The elimination of trade barriers and the liberalization of market facilitate the global trade substantially. To create an efficiency-oriented industry has already become a main driving force in the market where ports and shipping lines operate. In order to deal with the substantial challenge brought by the globalization process and the adoption of large-scale containers, both ports and shipping lines are dedicated in seeking effective strategies.

Horizontal and vertical cooperation, as forms of industry integration, become an important approach to improve the efficiency of shipping industry. In this section, an introduction of the horizontal and vertical cooperation which occurs in this market is provided. The two kinds of horizontal cooperation are discussed: namely, shipping lines cooperation, ports cooperation and one type of vertical cooperation; the cooperation between ports and shipping lines.

2.4.1. **Shipping lines cooperation**

Shipping lines play a prominent role in facilitating global trade. They not only enable the cross-region transport of the cargos, but also are involved in the marketing and commercial aspects in international trade. Hence to maintain shipping lines' competitiveness to provide efficient and effective service becomes critically important for the market (Panayides and Wiedmer, 2011).

However, the existence of high fixed cost, indivisibilities and other natures of shipping line, makes it difficult for a single shipping line to respond effectively and efficiently to the challenge of the market. Different forms of cooperation, to varying degrees, help the shipping lines enlarge the scope of their activities, rationalize their service, and reduce their costs (Bergantino and Veenstra, 2002).

The most prominent example in the history is the price-fixing agreements between shipping lines (Shashi Kumar, 1999). And there also exists fleet and route sharing agreement (Lu, Cheng, and Lee, 2006). Today, more encompassing and flexible form of cooperation has emerged, which is global strategic alliance (Bergantino and Veenstra, 2002).

The motivation of shipping lines cooperation

Given the dynamic environment of shipping market, increasing attention has been paid into the topic of economy of scale, cost control, service frequency and risk control. Horizontal cooperation among shipping lines offers an effective approach to obtain economy of scale, to share risk and investments, to provide better service to the users with a lower costs rate (Bergantino and Veenstra, 2002).

Using chain value concept, Panayides and Wiedmer (2011) divide the motivation into two types according to the types of resources contributed by the partners. In the first type, cooperation partners contribute similar resources to obtain economies of scale, rationalize service as well as to share risk. The other one is the situation that parties contributes complementary resources to develop their individual strength and to achieve competitive advantages. The second one has also been explained by (D.-W. Song and Panayides, 2002) and Panayides (2002) using the concept of Ricardian Rent. They believe that the combination of valuable scarce resources may bring the benefit to produce similar products at a lower cost, better products at a similar cost, or better products at an even lower cost.

Evangelista and Morvillo (1999) have also discussed the motivation from the perspective of supply chain integration. The motivations of the alliance are presented, such as the fierce competition and development of alliances among shipping lines. They find that most of the shipping line alliances emphasis on the phase of maritime transport. The objectives of the alliance are improving the service frequency and enlarging the scope of services. Panayides and Wiedmer (2011) conduct the empirical analysis of the three alliances, CKYH Alliance, New World Alliance and Grand Alliance, to investigate the motivation of the alliance agreement. Besides, other illustrations have also been made that the motivation includes financial, economic, strategic, operational and other aspects by researchers (Gardiner, 1997; Midoro and Pitto, 2000a).

Types of shipping line cooperation

The alliance of shipping lines can be divided into three types, which is strategic or global alliance, vessel sharing agreement and slot charter (Ferrari et al., 2008; Panayides and Wiedmer, 2011).

Strategic alliance

Global strategic alliance, which is defined as "*an agreement of two or more firms who attempt to enhance their competitive advantages collectively vis-à-vis competitors on a global marketplace*" (Bergantino and Veenstra, 2002), is the most prominent type of cooperation between shipping lines (Midoro and Pitto, 2000a).

Table 3 Three main alliances in the world

Alliances	CKYH	New World	Grand
Main partners	Hanjin Yang Ming K line COSCO	APL MOL HMM	Hapag-Lloyd OOCL MISC Berhad NYK Line
Capacity (TEU)	2120489	1595009	1730002
No. of vessels	414	293	368

Table 4 Detail information of alliances

Alliance	Shipping line	Capacity (TEU)	No. of vessels
CKYH	Hanjin	597881	102
	Yang Ming	390654	88
	Kline	350562	67
	COSCO	781392	157
	Total	2120489	414
New World	APL	626908	115
	MOL	593243	116
	HMM	374858	62
	Total	1595009	293
Grand	Hapag-Lloyd	773527	156
	OOCL	477579	106
	MISC Berhad	#	#
	NYK Line	478896	106
	Total	1730002	368

By sharing scarce sources and risks, and enhancing customer services, product quality and market accessibility, partners in a global alliance achieve a variety of competitive advantages than other and thus a profitability improvement (Bergantino and Veenstra, 2002). However, the alliances do not cover any joint sales, price-fixing, joint ownership of assets, joint of management functions or the share of profit or loss (Panayides and Wiedmer, 2011).

There are three main global strategic alliances in the world now, which are CKYH Alliance, Grand Alliance and New World Alliance.

Vessel sharing and slot charter

Vessel sharing agreement, as explained by (T. Heaver, Meersman, and Van De Voorde, 2001), is the cooperation that "*partner shipping lines work together to fulfil on a particular trade route through vessel sharing and performing joint optimization on their vessel departure times and shipping order assignment to vessels*." One important basis of vessel sharing is the sharing of demand information.

In slot sharing relationship, the partner shipping lines better have vessels deployed on the same route with different time schedules. By exchanging a fixed percentage of vessel capacity, the carriers can make a reduction of operating costs (Panayides and Wiedmer, 2011). However different types of cooperation exist in shipping market, there are still a number of shipping lines acting as soloists, like Maersk Line and MSC. The shipping line which is not in any relationship of cooperation usually has a large fleet and a wide service of network itself. For these big shipping lines, they do not necessarily need collaboration with the competitors. Economies of scale usually can be achieved by themselves.

Further study of shipping line cooperation

In spite of the obvious advantages that the shipping line cooperation has, it is claimed that some alliances have experienced instability (Alix et al., 1999) and are may not stable in long-term. Midoro and Pitto, (2000a) also find that most of the shipping line alliances have restructured or renewed their partners. According to a statistic of D.-W. Song and Panayides (2002), "*Various in-depth studies report failure rates of up to 80%, whereas dissatisfaction of one of the partners in the relationship almost always leads to the termination of the alliance*".

Midoro and Pitto (2000) find that the internal competition and complexity of alliance organization are the main reasons of the instability of alliance. Thus, they propose that decreasing the number of alliance members and differentiating the roles in market can enhance the stability of the alliance. And by a network analysis, Bergantino and Veenstra (2002) also find that network externalities are often offset by the coordination costs which is the main reason causes the instability of the cooperation. In addition, due to the continual restructuring with the shipping industry, the advantages of the coalition cannot reach its potential.

Khanna et al., (1998) note that "*it is the ratio of a particular firm's private to common benefits that affect its decision to stay in or quit the alliance*." The strategic alliances' stability is influenced by the consequent vulnerability and the mutual interdependence of the alliance partners to each other. A cheating may occurs when one carriers in the alliance finds it advantageous to maximize his own gains at the expense of the venture (Khanna et al., 1998).

In order to improve the stability of the alliances, Midoro and Pitto (2000) put forward three measures. The first one is to reduce the number of the partners. The second one is to differentiate their roles and contributions in cooperation. And the third one is the coordinating of sales and marketing activities.

2.4.2. Port cooperation

Such collaboration, is a method which is adopted in an attempt to reduce competitiveness when players are facing high level of competitive intensity (Ang, 2008). In recent years, a number of integrations have occurred in the transport industry in order to be remain competitive and to provide better service (T Heaver et al., 2001). Between ports, horizontal integration can lead to lower freight-rates and more efficient logistical control, thus an increasing demand for port service (Notteboom, 2002). Notteboom and Winkelmans (2001) also suggest that the cooperation between ports may generate a positive effect on the overall competitiveness of ports in a region; leading to a general growth of the market to the ports.

Motivation

The emergence of the Global Strategic Alliance increases the vessel size and greater the negotiating power of shipping lines (Hwang, 2010), making the competition in the shipping market more intense. In order to survive in such a dynamic environment, cooperation between ports is adopted often in adjacent regions (Avery, 2000). Large shipping lines may sometimes find themselves with terminal operators of the same power. The cooperation in ports affects the negotiating power of lines and increases the interest of terminals (T Heaver et al., 2001). Hwang (2010) also thinks that the formation of such a relationship arise due to complimentary resource or the functions they have, for instance the cargo flow between the ports and the hub-and-spoke networks. As a result, cost saving, resource pooling risk sharing and uncertainty reducing will be achieved.

Types of port cooperation

Considering the dynamic environment ports face, two new types of relationships are distinguished by Hwang (2010). The first one is "port coopetition", the second one is "complementary cooperation". Hwang (2010) regards that "*coopetition is a way of collaborating to compete which is compatible and mutually benefited strategies with different objectives can be strengthened when players are combined together*". Although ports play as competitors to each other, coopetition sometimes can lead a win-win result to competing ports. Comparing to this, "complementary cooperation" is facilitated by the need for other ports' functions or resources (Jasmine S. L. Lam and Yap, 2006). This kind of relationship is often developed in adjacent ports in a region or in a country. By conducting a research of ports in Taiwan, Hwang (2010) finds that a complementary cooperation may have a substantial positive effect on enhancing adjacent ports' overall competitiveness.

Further findings

Alongside the aforementioned researches, Saeed and Larsen (2010) apply a two-stage game to discuss a cooperative game among three container terminals in one port. They investigate the different combinations of coalitions and discuss the coalition's profit. The results show that the only stable coalition exists when all the terminals form a coalition. However, the terminal in other port will be the biggest winner. Furthermore, the geographic position, harbour depth, hinterland transportation network and port services are the essential motivation that drives the formation of complementary cooperation (Hwang, 2010). Sun and He (2008) use the Tianjin and Hebei ports as an example to investigate the port cooperation. They design an index system to evaluate the port logistics competiveness; the main index contains Economy of hinterland, the infrastructure, condition and service of port logistics and potential of hinterland logistics. It is further suggested that two ports form a coalition to enhance the competence of ports in the region. The alliance will help two ports to achieve the economic and social objectives.

2.4.3. Cooperation between shipping lines and ports

For there to exist cooperation between the shipping line and port; there are natural conditions which must exist for them to form a coalition. As shipping line and port are two different elements of maritime logistics and there is no direct competition between them, it makes the coalition easier and more profitable. Meanwhile, the vertical integration of shipping line and port can satisfy the maritime logistics efficiently and improve the service level.

Additionally, as it is shipping lines that choose where to berth their vessels, it has been increasingly critical for a port to cooperate with one or more shipping lines; to ensure a long-term prosperity. Shipping lines have been taking a number measures to obtain higher efficiency and lower costs. In order to achieve the improvement, adoption of large-size vessels and global strategic alliances came into existence (Asteris and Collins, 2010). As a result of this; small shipping lines struggle to survive and shipping lines are getting bigger and fewer. Hence being in a cooperation relationship with large shipping line can guarantee the interest of a port for a substantial period of time.

Though this process of integration exists widely in practise, there is still, due to the vast complexity, a lack of research on this subject. In this section, two kinds of relationships between shipping lines and ports are introduced.

Two types of cooperation between ports and shipping lines

Port investment

The subject of port investment, which is also known as a kind of joint venture, will be dealt with firstly. In the practice of port investment, a shipping line holds all or part of a terminal's share in a port. As a result, the shipping line's relationship with the port is complicated. On one hand, the shipping line will have priority for its own fleet to berth in the terminal when congestion occurs, which suggests that a cooperation has been built between the shipping line and the port. On the other hand, the terminal which is owned or partly owned by a shipping line can also provide service to other shipping lines' fleet, in which the shipping line actually is competing with the port. Musso et al. (2006) think that "*Port investment has already become a key issue in modern port economics with respect to planning port development, financing and assessing the return on investment*". Regarding the nature of port investment, J. Tongzon and Heng (2005) hold that port investment has a long-term payback and high capital cost.

Business cooperation

The second type of cooperation is business cooperation; in which case shipping lines do not hold any share of a port. A shipping line may choose to cooperate with a port only for a lower port fee, or priority to berth its fleet in the terminals, so that the shipping line can provide better service to shippers.

The benefit of cooperation between shipping lines and ports

In the shipping supply chain, there exits competition between shipping lines and amongst ports; however there is no direct competition between shipping lines and ports. Port investment can help shipping lines obtain a priority to use port terminals to ensure their cargo transport flow.

Shipping lines' benefits are as follow:

Vertical cooperation in the shipping supply chain helps shipping lines to expand their business upwards and downwards. By these means, they can reduce supply chain's internal cost and provide better service for customers.

The cooperation can help shipping lines reduce cost and gain a higher profit. In the event of port congestion, shipping lines can receive priority to terminal access by investing on a port. After the investment, a number of berth as well as operation efficiency will be guaranteed to the shipping line so that the line's transport schedule will not be delayed by port congestion and the risk will be reduced.

Port investment is a means to diversify the shipping line's income and risk. By attaining income return from the money invested in port operation; shipping lines can get a stable profit origin even in a trough point of shipping industry, which disperses a shipping line's risk.

Port's benefit from port investment

With the development of international trade, the demand for container transport increased sharply. For instance, in East Asia there remain numerous ports which need to expand their capacity. Many ports are facing congestion issues because of their poor facilities and budget limitation. Being in cooperation with shipping lines, a port can gain better access of carriers' funds, cargo flows and transport network to improve its service and capability; this enables them to achieve more market share.

Other researches about cooperation between shipping lines and ports

Besides those mentioned in the above introduction, there are some other papers dedicated to the area of cooperation between shipping lines and ports. Franc and Van der Horst (2010) investigate the cooperation between shipping line and port from the hinterland service integration. Much attention is given to the coordination contract. The limitations and advantages are presented by the empirical analysis. They find that although shipping lines and ports both expect to cut the cost through the integration, there remain substantial differences between the motivation of shipping lines and ports. Shipping lines are more concerned with the global scale which can improve their service and achieve a better market position. However, ports are more willing to broaden their hinterland scope. T Heaver et al. (2001) have investigated ports' strategies to locate the trends of the shipping industry, which reveal the integration in the maritime logistic chain. They hold that the coalition of shipping lines increases the market power of large liner alliances. In this circumstance, port authorities adopt a new strategy to cooperate with shipping lines. They also analyze the potential conflicts of interest for a port authority in matters related to the level of competition amongst terminals within a port and the amount of competition amongst ports.

2.5. Existing researches about the competition of ports

In addition to the researches mentioned above, there remains a vast amount of literature dedicated to this field. This section contains a summary of the key ideas and research methods adopted by several of the main sources of information on this topic:

Since the development of Asian foreign trade, ports become more and more important in Asian economies. An inevitable result is that the port competition becomes fiercer. Thus, the port competition in Asia has drawn much attention from scholars. (Comtois and Dong, 2007; Veenstra and Notteboom, 2011) have deeply investigated the development and competition in Chinese Yangtze River delta. (Cullinane et al. (2005) and Anderson et al. (2008) discuss the northeast Asian port competition. At the same time, there exists numerous studies on port competition in Southeast Asia (Kleywegt, Goh, Wu, and Zhang, 2002; Lam and Yap, 2008; Lobo and Jain, 2002; Minju, Chew, Lee, and Zhang, 2011; D. W. Song, 2002; Yap and Lam, 2006). Another of the key considerations of the researchers was that the competition not only exists among ports but also exists among different terminals in the same port. (Saeed and Larsen, 2010) apply a two stage game to study the competition among three terminals in Pakistan's Karachi Port. In the first stage, all the terminals should decide whether they cooperate with other terminals. This decision is based on the predicted payoffs of the second stage. The second stage is each coalition decides its price to compete with outside competitor.

As the port function keeps extended, competition between ports extends to port logistics systems competition. In recent years, some studies on hinterland accessibility and congestion have emerged (Wan et al., 2013; A. Yuen et al., 2008). Basso and Zhang (2007) takes congestion into game theory model. He discusses the relationship among shippers, carriers.

With the new trend of shipping industry, big shipping lines usually choose s few trunk ports to call, it increases competition. The former studies usually concern the competition of gateway demand, but the competition of transhipment cargos becomes more and more fierce. Minju et al. (2011) take Singapore as an example to discuss the competition of transhipment cargoes. A transhipment level parameter is introduced in this article.

Table 5 researches dedicated into port cooperation and competition in shipping industry

Author	Method	Topic
Veenstra and Notteboom (2011)		Introduction in Yangtze River Delta
Anderson et al. (2008)		Port competition in northeast Asia
Jasmine Siu Lee Lam and Yap (2008)		Port competition in south Asia
Minju et al. (2011)		Port competition in south Asia
D. W. Song (2002)		Port competition in south Asia
Jasmine S. L. Lam and Yap (2006)		Port competition in south Asia
Saeed and Larsen (2010)	Game theory	Terminal competition in Pakistan's Karachi Port
Sjostrom (2010)	Game-theoretical approach	The cooperation in liner shipping
Bergantino and Veenstra (2002)	Network theory	The shipping lines network
Panayides and Wiedmer (2011)	Game-theoretical approach	Global strategic alliance
Leong and Chen (2004)	Case study	Competition between Singapore and PTP
Yeo et al. (2008)	Case study	Factors influencing a Port's competitiveness
Gardiner (1997)	Lagrangian Method	Liner shipping
Anderson et al. (2008)	Dynamic game-theoretical approach	Competition in ports
Aboolian et al. (2007)	Static game-theoretical approach	Competition in ports

2.6. A review of related research

Given the rapid growth of the global economy, both ports and shipping lines need to adjust themselves to the dynamic environment of the shipping industry. In order to provide better service and further lower costs, different types of cooperation have been adopted by the shipping industry. Researchers have already created a vast body of work in the analysis of factors which influence a port's competitiveness. Additionally different types of surveys are also conducted to investigate the relative importance of these factors. However, as a major trend in shipping industry today, the subject of the cooperation between ports and shipping remains under researched. Qualitative methods have been adopted by the few existing ones, and seldom researchers focus on the influence of this type of cooperation of the above factors.

Considering this fact, this quantitative research is conducted to investigate the rationality of the cooperation between ports and shipping lines, as well as the influence on the players' strategies of different factors. Based on the above review, several factors can be regarded as the most important ones influencing the port's competitiveness, including port efficiency, hinterland connections, frequency of ships at ports and so on. Thus three factors to investigate separately are chosen.

2.7. Game theory

This section makes a little introduction to the method the research approaches, namely game-theoretical approach.

Game theory is a branch of modern mathematics. A strategic game deals with the situation of competition and conflict, a participant's choice not only depends on himself but also be influenced by choices of other participants. The final outcome is a result of choices of actions of all the participants (Von Neumann and Morgenstern, 2007).

2.7.1. The five essential elements in a game theory:

(1) players

In a game, each participant who is in a position to make decision is called "player". Only two players' game is called "two-player game" and more than two players' game is called "n-player game".

(2) Action

The choice that player can make at each stage in a game

(3) Strategies

A strategy is a whole action plan for playing the game, not a move for a stage of game but for what to do throughout the game.

(4) Orders

The order of decision making among players in game theory is very important. In some situations this is provided simultaneously to ensure fairness. There is also some situation players should decide sequentially. Different decision order makes different outcome of game. Therefore the regulation of the orders of the game is provided before continuing.

(5) Payoffs

The outcome of a game is called "payoffs". The payoff of each player depends on not only your own actions but also the other participants' choices of actions.

2.7.2. Types of game

The classification of game can be different according to different benchmarks.

In general, a game can be defined into cooperative game and non-cooperative game. The main differences between cooperative game and non-cooperative game are if there is any binding agreement between players. It is named "cooperative game" if there is binding agreement. Otherwise, it is named "non-cooperative game".

According to the order of decision making, people can divide a game into static game and dynamic game. Static game means every player move simultaneously; Dynamic game represents players move sequentially, and the player who move later can observe the decision who act first.

Based on how much a player understands the other participants, a division of the game into complete information game and asymmetric game is provided. Both non-cooperative game and cooperative game are applied in this research. They are both introduced in the following.

Non-cooperative game

Nash equilibrium

Nash equilibrium is an optimal solution in a non-cooperative game. It's one solution that no participant has a motivation to deviate from his chosen strategy. Overall, there is no incremental benefit from changing strategy while the other players remain their strategies (Nash, 1951). Nash equilibrium is only a best solution in non-cooperative game. However, it's not always the most efficient strategy. There are two kinds of non-cooperative game, Cournot and Bertrand models, are applied in this thesis, they are presented as follow.

Cournot model

Cournot model is a oligopolistic competition model was raised by (Cournot and Fisher, 1897). It's the earliest examples that lead to Nash equilibrium. It's a static game:

$$G = \left\langle N, \left(X_i\right), \left(\pi_i\right) \right\rangle$$

N the number of corporations that produce the same kind of product,

X_i production of corporation i, $i = 1, 2$

π_i payoff of corporation i when production is X_i respectively.

These two corporations face a conflict in the same market and above information are known by each corporation.

For the convenience of description, the following marks are introduced:

$$\bar{i} = \begin{cases} 2, i = 1 \\ 1, i = 2 \end{cases}$$

And

$$\pi_i\left(x_i, x_{\bar{i}}\right) = \begin{cases} \pi_1\left(x_1, x_2\right), i = 1 \\ \pi_2\left(x_1, x_2\right), i = 2 \end{cases}$$

For cooperation i, it doesn't know how much is $x_{\bar{i}}$, but it can choose x_i^* rationally for any $x_{\bar{i}}$:

$$\pi_i\left(x_i^*, x_{\bar{i}}\right) = \max_{x_i \in X_i} \pi_i\left(x_i, x_{\bar{i}}\right)$$

Also, x_i^* is obtained through above equation and it's a function of $x_{\bar{i}}$, to denote:

$$x_i^* = f_i\left(x_{\bar{i}}\right)$$

It is assumed that x_i^* is the best response function, $i = 1, 2$.

If x_1^* and x_2^* satisfy:

(1) $x_i^* \in X_i$, $i = 1, 2$

(2) $x_1^* = f_1\left(x_2^*\right)$

(3) $x_2^* = f_2\left(x_1^*\right)$

Then, $\left(x_1^*, x_2^*\right)$ must be the Nash equilibrium of this game.

Cooperative game

In the non-cooperative game, the prisoners' Dilemma is a famous example. However, if both players can cooperate on the "keep silent, keep silent" strategy, they will do better than the strategy "confess, confess". So, cooperative game is more efferent than non-cooperative game.

In a cooperative game, there are two essential conditions must be satisfied: (1) Each player can gain more benefit by cooperating than non-cooperating. (2) It's possible to reach binding agreements among players.

The most important issue of cooperation is fair allocation, either transferable utility games or non-transferable utility games. Transferable utility game means that the outcome of the game is given to the whole group and allocates it to the group members. Non-transferable utility game represents that the outcome of actions is given to individual group members.

Here are some important definitions:

Definition 1 A pair of payoffs (u, v) in a cooperative game is jointly dominated by (u_1, v_1) if $u_1 \geq u, v_1 \geq v$, and $(u_1, v_1) \neq (u, v)$.

Definition 2 A pair of payoffs (u, v) is Pareto optimal if it is not jointly dominated.

For n-person cooperative game, a coalition S is some subset of $N = \{1, 2, 3, ...n\}$.

Definition 3 The characteristic function of an n-person game assigns to each subset S of the players the maximum value $V(S)$ the coalition S can guarantee itself by coordinate the strategies of its members, no matter what the other players do.

According to the definitions above, the imputation is defined as follow:

Definition 4 An imputation in an n-person game with characteristic function v is a vector $x = (x_1, x_2, x_3, ..., x_n)$ satisfying: (1) $\sum_{i=1}^{n} x_i = v(N)$ and (2) $x_i \geq v(i)$, $i = 1, 2, ..., n$. Then an imputation is Pareto optimal (Rao, 1987).

To ensure the stability of coalition, an understanding of how the cooperative game played is required. First, players are still selfish even they cooperate with other players, so the individual group member must benefit from cooperation. Second, the coalition and payoffs allocation should satisfy that no participants in the group have a motivation to deviate. Third, if it's possible the distribution of payoffs is proportion to its contribution to the group. So, the most important definition core (Aumann, 1961) is represented as follow:

Definition 5 The core of a game v, denoted by $C(v)$, is the set of imputation which are not dominated for any coalition. And x is a core if and only if: (1) $\sum_{i=1}^{n} x_i = v(N)$ and $\sum_{i=1}^{n} x_i = v(N)$ for all S.

The aim of all the ground work is to support the model. Then, a two-stage game model will be constructed: corporative stage and non-corporative stage. Finally, using empirical information, further analysis of the model will be made; in order to obtain a greater insight of the issue.

3. Methodology

3.1. Research question

As discussed previously, cooperation between ports and shipping companies can lead to a vast change to regional shipping markets. Both ports and shipping lines may face a severe challenge when confronted with losing a of partner. However, the cooperation is still short of research, especially for quantitative research. Hence, the authors start this paper with the following questions:

1. What is the relationship among shipper, shipping line and port?
2. Is this cooperation good for any combination of ports and shipping lines?
3. How will the cooperation be given different conditions of the factors?
4. What is best strategy for each player in the game?
5. What is influence of this cooperation on the shipping industry?

3.2. Research paradigms

A research paradigm is a philosophical framework that guides how scientific research should be conducted (Collis and Hussey, 2009). Two main paradigms can be used in a scientific research, which is positivism and interpretivism. In a research guided under positivism, the theory can be found by empirical research because reality is believed to be independent of us. On the contrary, in a research guided by interpretivism, people believe that social reality is shaped by our perceptions, thus it is highly subjective. (ibid)

This research, however, is conducted partly under the guide of positivism and partly interprevitism. As this paper will investigate the cooperation between ports and shipping lines by a model, a series of assumptions are made, in which some factors are considered important for a port's competitiveness. Besides literature review, a number of interviews are also conducted. The respondents are all experts in the related fields. Based on the experts' answers, the influence of the factors will be further discussed and thus the rationality of the assumptions will be ensured, which is considered under the guide of interpretivism. In comparison to this, after the model is created, a numerical test will be conducted to show the payoffs of each player. By analyzing the numerical results, the conclusion of this research will be made.

3.3. Research design

The research is presented firstly with literature review. By literature review, the main players in the shipping industry and the important factors influencing ports' competitiveness are summarized. Additionally different types of cooperation within the shipping industry are investigated. Using the findings from the literature, the factors' influence on the cooperation will be investigated. Previous to this, a series of interviews will be conducted to support the assumptions of the model. Secondly a model is created to analyze the choice of shipping lines and ports using game-theoretical approach. Finally, the findings of modeling analysis will be used in a analysis of Shanghai Port and Busan Port; which is considered as an application of this research.

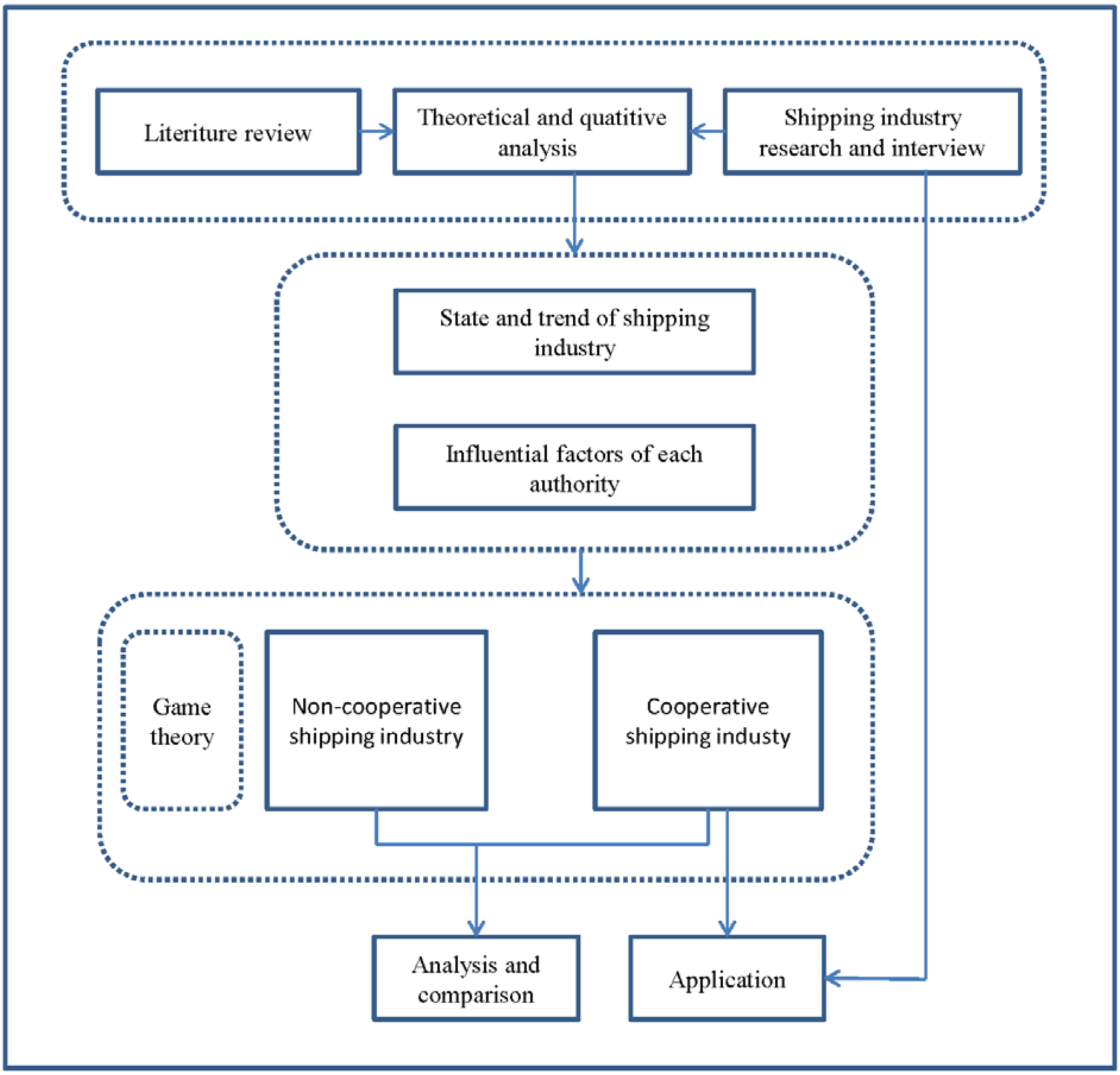


Figure 5 Basic illustration of our research

3.4. Research method

Model, game-theoretical approach and interview are used in this paper. The authors create a model to analyze the utility of ports and shipping lines. Using game-theoretical approach, the best strategies of ports and shipping lines are discussed. Additionally, interviews are also used to collect the experts' perspective on the topic, which will be discussed in data collection section.

3.4.1. Modelling

A model can be defined as a tool with which a problem may be addressed. Models are created in order to tackle problems and are thusly closely related to the problem they were created to solve (Hägg and Wiedersheim-Paul, 1994). Models exist to represent a certain reality and provide a simplification of that reality. In the creation of such simplifications it is crucial to identify the basis of the key concepts being modelled. As such, unimportant and expendable factors of the reality can be ignored. It must be borne in mind however that there can be no fixed, unchanging, representation of reality and it is therefore open to interpretation. As such varying interpretations can exist, models on the same reality can exist in numerous different forms; with neither being "correct" or "incorrect". This connection is illustrated in Figure 6.

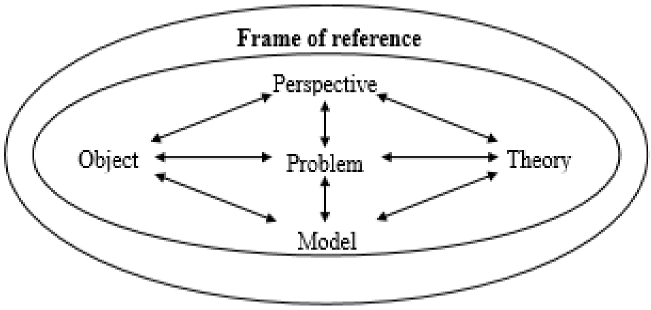


Figure 6 Frame of models

Source: (Hägg and Wiedersheim-Paul, 1994, p. 12)

In this study, model is used to describe the influence of the factors and the profit of ports and shipping lines. By analyzing the results of a numerical test, a conclusion will be obtained. In order to ensure the stability of the results, sensitivity analysis will also be conducted.

3.4.2. Game Theory

Game-theoretical approach is also used in this paper. Since one of the objectives of this research is to investigate the rationality of cooperation, two types of game are applied in this analysis, namely cooperative game and non-cooperative game. By comparing the different payoffs in these two games of each player, the players' decision, as to whether to cooperate or not, is made.

3.5. Data collection

Quantitative data refers to the data in numerical form, comparing to this, qualitative data have to be understood within context (Collis and Hussey, 2009). Given the method this research approaches, both qualitative and quantitative data will be collected and used.

3.5.1. Primary data

Primary data is collected directly from first-hand and original source and perceived as more reliable than secondary data as it is particular and contextual to the specific topic (Collis and Hussey, 2009).

Interview

In this research, interviews have been conducted. In interviews, participants are asked questions about their behaviour, feeling and perspectives (Collis and Hussey, 2009). Three types of interviews could potentially be conducted including structured interview, semi-structured interview and unstructured interviews.

Semi-structured interview is adopted in this research. In a semi-structured interview, interviewers have to prepare a series of question and more questions can be added when the interviewer find necessary to obtain detailed information. In order to gain knowledge of the factors influencing the ports' competitiveness and the cooperation between ports and shipping lines, semi-structured interviews were held. Experts from different fields and different regions were chosen to reduce bias in the sample. Among the four interviews the authors conducted, one respondent is from China and the other three are from Gothenburg, Sweden. The professions of participants interviewed include: a University professor, Vice president in Port Authority and experienced journalist in shipping industry. Additionally, a questionnaire is prepared beforehand. The questions have a sequential order and are all open-ended to ensure that the expression would not affect the respondents' answers.

Table 6 List of interviews

Kevin Cullinane	Professor of Logistics and Transport Economics at University of Gothenburg	Gothenburg, Sweden
Honglei Ge	Associate professor, Ningbo Institute of Technology, Zhejiang University	Ningbo, China
Nils-Erik Lindell	Journalist in Shipping and Logistics	Gothenburg, Sweden
Claes Sundmark	Vice President, Sales and Marketing, Port of Gothenburg	Gothenburg, Sweden

3.5.2. Secondary data

Secondary data is the data which has already been published (Collis and Hussey, 2009). It can be collected from databases, newspapers or other publications.

Literature review

A literature review is a pragmatic evaluation of the existing knowledge on a particular topic. In order to develop the theoretical framework concerning the cooperation between ports and shipping lines, a review of relevant and recent literature has been conducted (Collis and Hussey, 2009). A great deal of literature review has been done using the databases of Gothenburg University. In order to get a comprehensive understanding of the knowledge, a variety of keywords were used including *"port competitiveness", "port efficiency", "hinterland conditions", "frequency of ships at port", "port call", "port congestion", "port cooperation", "integration in shipping market", "cooperation between ports and shipping lines", "global alliance", "port investment" etc.*

Data for application

Besides literature review, another group of secondary data is also needed in the application. Thus, the authors obtain the data of port and its basic hinterland demand from the official sites of Port Authority and Custom sites of the governments. In order to guarantee the reliability of these data, all the information collected are published by official party.

3.6. Research quality

3.6.1. Validity

To be of validity means the findings reflects the phenomenon under the research accurately (Collis and Hussey, 2009). Validity is one important issue for the quality of the research, especially for modelling research. In order to improve the validity of this research, huge efforts have been put into the theoretical framework, which is used as a support for the rationality of the assumptions made in this paper. Additionally a number of interviews have been conducted to further prove that the factors have been used correctly.

3.6.2. Reliability

Reliability means consistency of the results even in repeated researches (Collis and Hussey, 2009). Reliability is another important issue for the creation of a research. Several measures have been adopted in this research in order to improve the reliability of the research. As illustrated by (Collis and Hussey, 2009), inter-term correlation can be considered as an index of reliability. When designing the questionnaire, the questions are designed to be relevant with each other. Due to the relationship between different factors, the participants may explain an opinion twice in the interview, which also complies with the principle of *Test re-test method*. When conducting the interview, in order to eliminate any bias within the sample, participants are chosen from different professions and regions. Additionally, regarding the data collected for the application, all the data is collected from governmental or official authority sites. Thus the reliability is guaranteed.

In this research, anthers will use multiple methods to verify both invalidity and reliability, triangulation is the most important skill applied in this research. "*triangulation is the use of multiple sources of data, different research methods and/or more than one research to investigate the same phenomenon in a study*" (Collis and Hussey, 2009). There are four types of triangulation as stated by Easterby-Smith (1991): triangulation of theories, data triangulation, investigator triangulation and methodological triangulation. In the part of literature review, theories from different researchers and subjects are summarized to provide a valid basis for this research. Besides, during the qualitative research, data triangulation method is applied by collecting information from various sources. A simple way to use multiple sources of data is to ask several respondents similar or even the same question; several interviewees are involved in the process of interview, and similar responses are obtained thus the validity and reliability of this research can be guaranteed.

3.7. Limitations

As a simplification of reality, model research has its limitations. The authors believe that two types of limitations should gain attention in this research.

The first limitation discussed, is the difference between the reality and the simplification of reality. Cooperation between ports and shipping lines is generally perceived as a complicated topic among researchers. The decision made by players to choose a partner is influenced by complicated factors. However, in order to make the model simpler, the authors only choose basic hinterland demand, congestion condition (efficiency at a port), and frequency of ships etc as the main factors influencing the formation of this relationship. Factors also considered to influence the cooperation are removed from this research such as long-term relationship and governmental regulation. To ensure the rationality of the assumptions and reduce the negative effects of this limitation, a series of interviews are conducted. Thus the assumptions attain further support from the experts' perspectives.

The second limitation can be understood as the dimensions of the model. Since the reality is complicated, it is too difficult to create a model describing all the scenarios. In similarity to the approach of other game theory applications, only one kind of scenario is analyzed in this research. In which, only one shipping line can choose to cooperate with ports and this shipping line can only choose one port to cooperate with, and only financial aspects are taken into consideration. However, due to the complexity of the topic, seldom have researchers conducted similar researches quantitatively. This research is aimed to be a breakthrough in this field. Thus, only one scenario is studied. More scenarios possibly may be conducted in further researches.

4. Models

With the rapid development of International Trade and technology, new trend has taken place in the modern shipping industry. Container shipping lines shift to larger vessels, it have turned the shipping route structure into hub-and-spoke. In order to become the shipping hub port, transhipment and port call have become the central battleground of port competition. This transformation intensifies competition among ports, so large port has taken aggressive measures to address these challenges. These measures involve port expansion, deep-water port construction and managerial improvement. Meanwhile, cooperation becomes an effective means of enhancing ports' competitiveness. In order to investigate the rationality and influence of the cooperation in shipping industry, the maritime transportation demand is firstly introduced.

4.1. Demands

According to the studies about port choice from shippers' perspective, the most influential ingredients transportation fees and the frequency of port calls as the factors affect the demand in this model are applied. First, transportation fees are composed by fees charged by port per container and fees charged by shipping line per container. Among the shipping lines, it is assumed that they maintain the equivalent number of ships and service level. Furthermore, both the pricing and cost per container charged by shipping line are assumed to be identical, using P and c to notate it. Second, it is considered that the frequency of port calls is a factor which affects the transhipment demand. The container handling demand obtained at port i can be formulated as follow:

$$Q_i = V_i - d_1 \left(P + \mu_i \right) + d_2 \eta_i \tag{1}$$

where Q_i is the total handling demand of the port i. V_i represents the basic hinterland cargo handling demand at port i. P means constant fees charged by shipping lines per container. μ_i is fee charged by the port i. η_i is the frequency of ship calls at port i. d_1 is the coefficient of how price affects total demand of a port. d_2 is the coefficient to describe the effects of port call on transhipment demand of a port.

V_i, the basic hinterland cargo handling demand, cargo being transported directly to the final destination, depends on the size of hinterland, hinterland's volume of import and exports commerce and inland distributing network. It is considered to be relatively stable, since there are substantial savings in transportation costs and time.

According to the new trend of the shipping industry, hub-and-spoke, the frequency of port calls becomes a key competitive factor for ports. Especially, it has significant influences on attracting transhipment cargos (Minju et al., 2011). Thus, the frequency of port calls to the cargo demand function to evaluate the volume of transhipment cargos is added.

Furthermore, in order to analyze each shipping line's condition, the cargo handling volume of each shipping line is evaluated. It is assumed that container cargo volume of every shipping line is proportional to its frequency of ship calls at that port. Thus the container handling demand of shipping line j at port i can be formulated as follow:

$$Q_{i,j} = Q_i \frac{\eta_{i,j}}{\eta_i} \tag{2}$$

Where $\sum_{j=1}^{N} \eta_{i,j} = \eta_i$, and $\eta_{i,j}$ represents the frequency of ship calls arranged by shipping line j at port i.

It is necessary to impose additional constraints to guarantee the rationality of the model: (1) the cargo handling demand of shipping line at each port must be non-negative; (2) the price charged by port must be non-negative; (3) the frequency of ship calls arranged by shipping line at each port must be non-negative. These constraints are as follow:

(S1) $Q_{i,j} \geq 0$

(S2) $\mu_i \geq 0$

(S3) $\eta_{i,j} \geq 0$

In order to analyze the influence of collaboration on shipping industry, the non-cooperative game is discussed first.

4.2. Non-cooperative game

In recent years, the global shipping industry is developing rapidly, every country and district seek a piece of marine economy. A lot of construction or expansion of the ports appear, the competition among ports become fiercer. In contrast, Oligopolies with adequate resources and financial support, e.g., COSCO and Maersk, monopolize major international shipping lines. Major carriers are intending to form an alliance for the cooperation of fleet. They are capable of negotiating with ports. In this situation, it is considered that it is a simultaneous move game between shipping lines and ports. Since the new ship replenishment cycle is long, the number of vessels in shipping market is fixed for a short period of time. It is assumed that there are N shipping lines in the market and the number of total available ships of each shipping line in certain unit time period is constant R.

The following profit function and constraint of each shipping line is proposed:

$$\text{Max:} \quad v\left(ship_j\right) = \sum_{i=1}^{2} \left[\left(P - c - \beta D_i \right) Q_{i,j} - S\eta_{i,j} \right], \; j = 1, 2, \ldots, N \tag{3}$$

$$\text{St.} \qquad \sum_{i=1}^{2} \eta_{i,j} \leq R \tag{4}$$

Where P is the revenue per container charged by shipping line and c is the shipping line's operation cost per container. They are assumed to be identical and constant. D_i is the congestion delay time per container at port i which depends on the total handling demand and capacity of port i. This is considered as a cost component, since the congestion delay time becomes an additional cost to shipping lines. β is the shipping line's value of time. S is the fixed cost of dispatching a ship.

The function (3) maximizes the total profit of each shipping line in both two ports, and the cost for delegating ships is considered in our model. Meanwhile, the cost of dispatching ships is also an important factor determines the ships quantity shipping lines are willing to supply, the cost in our model is also added. Constraints (4) restrict the frequency of port calls that each shipping line can delegate.

$D_{i,}$ the congestion delay time is mainly determined by the volume of cargo handling demand and the cargo handling capacity. There are multiple factors determine port's cargo handling capacity, such as cargo handling efficiency, hinterland distributing network system, port's administrating level and port's infrastructures. The congestion delay function in Basso and Zhang (2007) is used in our model:

$$D_i = \frac{Q_i}{K_i},\ i = 1,2 \tag{5}$$

where K_i is the cargo handling capacity of port i.

Having discussed the shipping lines' profit function, an analysis of the ports' circumstances is provided. Rivalry between two ports are investigated, each port decides its price to maximize own profit. The profit function of port can be formulated as follow:

$$v\left(port_i\right) = \left(\mu_i - O_i\right)Q_i - m_i K_i,\ i = 1,2 \tag{6}$$

where O_i denotes the operation cost of port i and m_i is the marginal capacity cost of port i. It is presumed that the ports' value and capacity value are separable and that the marginal cost remains the same (Basso and Zhang, 2007).

Lemma 1 Shipping line j's profit $v(ship_j)$ is strictly jointly concave in $\eta_{1,j}$ and $\eta_{2,j}$.

Proof. See the Appendix 1.

Lemma 2 Port i's profit $v(port_i)$ is strictly concave in μ_i.

Proof. It's easy to obtain $\frac{\partial^2 v\left(port_i\right)}{\partial \mu_i^2} = -d_1 < 0$, thus $v(port_i)$ is strictly concave in μ_i.

Thus there exists a Nash equilibrium point which solves the above Nash game (3), (4) and (6). The optimal solution cannot be given on a closed form in this case. Therefore this will be explored through numerical experiments.

4.3. Cooperative game with external competitors

In this section, the cooperative game, shipping line and port, with external competitors is discussed. An assumption of the following is taken:

As significant strategic resources, port relates to national economy security. It has a lot of restrictions on the coalition of port and shipping line. Furthermore, the two motivation of port to cooperate with shipping line mainly are obtaining financial support and advanced port management experience. So there are only a certain number of shipping lines meet these requirement. Thusly, the shipping lines are classified in to two types: (1) qualified shipping line and (2) unqualified shipping line.

As the same assumption as non-cooperative game, it is assumed that there are *N* shipping lines in the market and the number of each shipping line's available ships in certain unit time period is constant *R*. Furthermore, it is assumed that there is only one shipping line, which is the qualified shipping line that has access to forge a coalition with port and the other shipping lines are impossible to establish coalition with port. Meanwhile, once a port cannot become the main port it will definitely turn to a feeder due to fierce competition in the region. Therefore it is assumed that no shipping line will cooperate with two ports at once, that is to say, the shipping line can only choose one port as its partner.

A two-stage game scenario that involves two ports and multiple shipping lines is established. In the first stage, shipping lines and ports decide on the cooperative strategy based on their prediction. The second stage is modelled as a static game with the coalition and the others that have not joined the coalition. The coalition's profit function and singletons' profit function are formulated as follow.

4.3.1. Coalition

In the case of cooperative game, shipping line and port can establish different combinations of coalition. For the convenience of description, it is assumed that only the shipping line *N* has the ability to forge a coalition with the port. Without loss of generality, the consolidation of shipping line *N* and port 1 is discussed. This scenery is similar to the one in which shipping line *N* cooperate with port *2*. Then the profit function of the coalition can be formulated as follow:

$$\text{Max: } v\left(ship_N \cup port_1\right)=\sum_{i=1}^{2}\left[\left(P-c-\beta D_i\right)Q_{i,N}-S\eta_{i,N}\right]+\left(\mu_1-O_1\right)Q_1-m_1K_1 \quad (7)$$

$$\text{St. } \quad \eta_{1,N}+\eta_{2,N}\le R \quad (8)$$

4.3.2. Singletons

As the similar way of non-cooperation, the profit of port *2* can be formulated as follow:

$$v\left(port_2\right)=\left(\mu_2-O_2\right)Q_2-m_2K_2\,. \quad (9)$$

The profit of shipping lines which act as a singleton are calculated as follow：

$$\text{Max: } v\left(ship_j\right)=\sum_{i=1}^{2}\left[\left(P-c-\beta D_i\right)Q_{i,j}-S\eta_{i,j}\right],\quad j=1,2,...,N-1 \quad (10)$$

$$\text{St. } \quad \eta_{1,j}+\eta_{2,j}\le R\,,\ \ j=1,2,...,N-1 \quad (11)$$

Lemma 3 The coalition's profit $v\left(ship_N \cup port_1\right)$ is strictly jointly concave in $\eta_{1,N}$, $\eta_{2,N}$ and μ_1.

Proof. See the Appendix 2.

Lemma 4 The port 2's profit $v(port_2)$ is strictly concave in μ_2.

Proof. It can be obtained that $\frac{\partial^2 v\left(port_2\right)}{\partial \mu_2^{\,2}}=-d_1<0$, thus $v\,(port_2)$ is strictly concave in μ_2.

Lemma 5 Shipping line *j*'s profit $v(ship_j)$ $(j=1,2,\ldots,N-1)$ is strictly jointly concave in $\eta_{1,j}$ and $\eta_{2,j}$.

Proof. The proof of lemma 5 is similar to lemma 1, thus see the Appendix 1.

According to Lemma 3, Lemma 4 and Lemma 5, there exists a Nash equilibrium point which solves the above Nash game (7), (8), (9), (10) and (11). The optimal solution cannot be given in a closed form in this situation. Therefore, it will be explored through numerical experiments.

4.4. Shippers' surplus

On the basis of discussion of the profit of shipping lines and ports; an analysis of the effect of coalition on the shippers' benefits is also needed. Then the rule of the half is applied to estimate the change of shippers' surplus (Williams and Senior, 1977). Thus the difference in shippers' surplus is formulated as follow:

$$\Delta SS_i = \frac{1}{2}\left(SC_0 - SC_i\right)\left(X_i + X_0\right) \text{ , } i = 1,2 \tag{12}$$

ΔSS_i : change in shippers' surplus after shipping line N forms an alliance with port i.

SC_i : cost of shippers after shipping line N forms an alliance with port i.

SC_0 : cost of shippers in non-cooperative game.

X_i : cargo handling demand after shipping line N forms an alliance with port i.

X_0 : cargo handling demand in non-cooperative game.

4.5. Cooperation Mechanism

In order to discuss the cooperative strategy of this game, there is a need to explain the cooperation mechanism. Firstly, an introduction of the definition of characteristic function and its properties is provided.

For *n*-person cooperative game, a coalition *S* is some subset of $N=\{1,2,\ldots,n\}$. The characteristic function of an *n*-person game assigns to each subset *S* of the players the maximum value that coalition *S* can guarantee itself by coordinate the strategies of its members, no matter what the other players do.

The characteristic function has two properties:

(1) Normalization: $v(\phi) = 0$, where ϕ represents an empty set.

(2) Superadditivity: $v(p_1 \cup p_2) \geq v(p_1) + v(p_2)$

An imputation in an n -person game with characteristic function v is a vector $x = (x_1, x_2, x_3, \ldots, x_n)$ satisfying:

(1) Individual rationality: $x_i \geq v(i)$, $i = 1, 2, ..., n$

(2) Collective rationality: $\sum_{i=1}^{n} x_i = v[P]$, $i = 1, 2, ..., n$.

For the case of study, the differing coalition profit is defined as follow:

$$\delta_{1,N} = v(ship_N \cup port_1) - v(ship_N) - v(port_1) \quad (13)$$

$$\delta_{2,N} = v(ship_N \cup port_2) - v(ship_N) - v(port_2) \quad (14)$$

Where $v(ship_N \cup port_i)$ means is the coalition profit of shipping line N and port i, $v(ship_N)$ is the profit of shipping line N when all the players are acting independently and $v(port_1)$ represents the profit of port i when all the players are acting independently.

The definition of $\omega = \max\{\delta_{1,N}, \delta_{2,N}, 0\}$ is provided. The situation $\omega=\delta_{1,N}$ or $\omega= \delta_{2,N}$ satisfies the superadditive property, the individual payoff may be less in the coalition than when it was working alone, however, this is due to the fact that the fee profit distribution among coalition is disregarded. In this paper, it is assumed that the profit will be distributed perfectly to maintain the coalition. When $\omega=0$, this situation does not satisfy the superadditive property of the characteristic function. The formation of this coalition is not possible since at least one player can get a better payoff by working alone. Thus, the cooperation mechanism is given in the following.

(1) If $\omega = \delta_{1,N}$, coalition of *Port* 1 and shipping line N.

(2) If $\omega = \delta_{2,N}$, coalition of *Port* 2 and shipping line N.

(3) If $\omega = 0$, shipping line N will act as a singleton.

5. Numerical analysis

In this section, an exploration of the results through a set of numerical experiments in order to obtain best strategy of shipping lines and ports in provided; particularly a comparative analysis between non-cooperative game and cooperative game. Some useful managerial guidelines are also provided in this section. In section 5.1, a sensitivity analysis of three main parameters of two models is discussed. In section 5.2, an analysis of the best strategy in non-cooperative game is presented. In section 5.3, the results of cooperative game and the comparative analysis with respect to the non-cooperative game are presented. The initial values of key parameters are given by: d_1=1, d_2=0.1, $S=13$, $P=10$, $c=2$, $N=3$, $R=2$, $\beta=3$.

5.1. Sensitivity analysis

In order to ensure the stability of the model, a series of sensitivity analyses are provided. An investigation of the effects of parameters d_1, d_2 and β on η, μ, Q, *v(ship)* and *v(port)* in both non-cooperative game and cooperative game is then taken. In order to test the model, some values of the variables are initialled: $K_1= 20$, K_2=20, $V_1=25$, $V_2=20$. The sensitivity analyses focus on single variable analysis, no variable combination will be treated in this part. The default values for sensitivity analyses are as below:

Table 7 Sensitivity analysis of the non-cooperative game with respect d_1

d_1	$\eta_{1,j}$	$\eta_{2,j}$	μ_1	μ_2	Q_1	Q_2	SL_j	$P1$	$P2$
0.8	1.01	0.75	10.81	7.64	8.65	6.11	10.92	93.55	46.71
0.9	0.96	0.7	9.05	6.23	8.14	5.6	10.27	73.69	34.90
1	0.91	0.64	7.64	5.1	7.63	5.09	9.6	58.31	25.97
1.1	0.86	0.58	6.48	4.17	7.13	4.59	8.92	46.2	19.13
1.2	0.81	0.52	5.52	3.4	6.62	4.08	8.22	36.53	13.86

* *SL* represents for the profit of shipping line. *P* represents for the profit of port. The same below

Table 8 Sensitivity analysis of the cooperative game with respect d_1

d_1	$\eta_{1,N}$	$\eta_{2,N}$	$\eta_{1,j}$	$\eta_{2,j}$	μ_1	μ_2	Q_1	Q_2	SL_j	SL_N	$P1$	$P2$
0.8	1.22	0.75	1.04	0.75	9.88	7.64	9.42	6.11	10.66	11.69	93.14	46.71
0.9	1.16	0.7	1.01	0.7	8.11	6.23	9.02	5.6	10.22	11.05	73.15	34.9
1	1.09	0.64	0.98	0.64	6.68	5.1	8.63	5.09	9.76	10.41	57.62	25.97
1.1	1.04	0.58	0.95	0.58	5.52	4.17	8.22	4.59	9.24	9.77	45.38	19.13
1.2	0.98	0.52	0.91	0.52	4.55	3.4	7.82	4.08	8.7	9.12	35.59	13.86

Table 9 Sensitivity analysis of the non-cooperative game with respect d_2

d_2	$\eta_{1,j}$	$\eta_{2,j}$	μ_1	μ_2	Q_1	Q_2	SL_j	*P1*	*P2*
0.06	0.9	0.63	7.58	5.06	7.58	5.05	9.66	57.47	25.57
0.08	0.9	0.64	7.61	5.08	7.61	5.07	9.63	57.89	25.77
0.1	0.91	0.64	7.64	5.1	7.63	5.09	9.6	58.31	25.97
0.12	0.91	0.64	7.66	5.12	7.67	5.11	9.57	58.74	26.17
0.14	0.92	0.65	7.69	5.14	7.7	5.13	9.54	59.18	26.38

Table 10 Sensitivity analysis of the cooperative game with respect d_2

d_2	$\eta_{1,N}$	$\eta_{2,N}$	$\eta_{1,j}$	$\eta_{2,j}$	μ_1	μ_2	Q_1	Q_2	SL_j	SL_N	*P1*	*P2*
0.06	1.04	0.63	0.98	0.63	6.64	5.06	8.54	5.05	9.99	10.38	56.7	25.57
0.08	1.07	0.64	0.98	0.64	6.66	5.08	8.58	5.07	9.87	10.39	57.16	25.77
0.1	1.09	0.64	0.98	0.64	6.68	5.1	8.63	5.09	9.76	10.41	57.62	25.97
0.12	1.12	0.64	0.98	0.64	6.71	5.12	8.66	5.11	9.62	10.42	58.12	26.17
0.14	1.15	0.65	0.99	0.65	6.73	5.14	8.71	5.13	9.5	10.43	58.6	26.38

Table 11 Sensitivity analysis of the non-cooperative game with respect β

β	$\eta_{1,j}$	$\eta_{2,j}$	μ_1	μ_2	Q_1	Q_2	SL_j	*P1*	*P2*
1	1.02	0.69	7.65	5.1	7.65	5.11	10.46	58.56	26.04
2	0.96	0.66	7.64	5.1	7.65	5.1	10.03	58.44	26.01
3	0.91	0.64	7.64	5.1	7.63	5.09	9.6	58.31	25.97
4	0.85	0.62	7.63	5.09	7.63	5.1	9.17	58.19	25.93
5	0.8	0.59	7.62	5.09	7.62	5.09	8.74	58.07	25.9

Table 12 Sensitivity analysis of the cooperative game with respect β

β	$\eta_{1,N}$	$\eta_{2,N}$	$\eta_{1,j}$	$\eta_{2,j}$	μ_1	μ_2	Q_1	Q_2	SL_j	SL_N	*P1*	*P2*
1	1.28	0.69	1.15	0.69	6.41	5.1	8.95	5.11	10.95	11.69	57.36	26.04
2	1.18	0.66	1.07	0.66	6.55	5.1	8.78	5.1	10.33	11.03	57.52	26.01
3	1.09	0.64	0.98	0.64	6.68	5.1	8.63	5.09	9.76	10.41	57.62	25.97
4	1.01	0.62	0.91	0.62	6.82	5.09	8.46	5.1	9.2	9.81	57.71	25.93
5	0.93	0.59	0.83	0.59	6.94	5.09	8.32	5.09	8.66	9.24	57.74	25.9

From the sensitivity analyses results (Table 7 to

Table 12), some observations can be made. First, when the value of d_1 become smaller to 0.9, which means shippers give less regard to port cost and the increase of port cost will have less influence on the total handling demand *Q*, both port cost and total handling demand will increase. As a result, profits of ports and shipping lines increase. The same results shows up in the case of cooperative game (Table 8). Second, d_2 measures the importance of port call $\eta_{1,N}$

on attracting transhipment cargo, specifically, how the ship frequency will influence the total handling demand. According to

Table 9 and Table 10, the change of d2 will have minimal effect on the other variables and the final results. Third, according to Table 11and

Table 12, when shipping line's value of time β increase, in order to reduce congestion cost, shipping lines intend to reduce port call $\eta_{1,N}$. As shown in

Table 12, $\eta_{1,N}$ falls to 0.85 when Beta grows to 4. However, because port cost μ_1 falls too, the reduction of port call $\eta_{1,N}$ does not affect the total hinterland demand Q substantially; remaining relatively the same. The total profit of ports and shipping lines decreases due to the formal changes.

5.2. Non-cooperative game

In this section, a discussion of the effect of hinterland differences on the decisions of shipping lines and ports in non-cooperative game is provided. In the numerical analysis following, it should be assumed that K_1=20, K_2=20, V_2=20, if there is no specification. It must be highlighted that although shipping line N is qualified to cooperate with ports, it would contribute anything in the non-cooperative game. Thus all the shipping lines are identical in this section (j=1, 2,…, N).

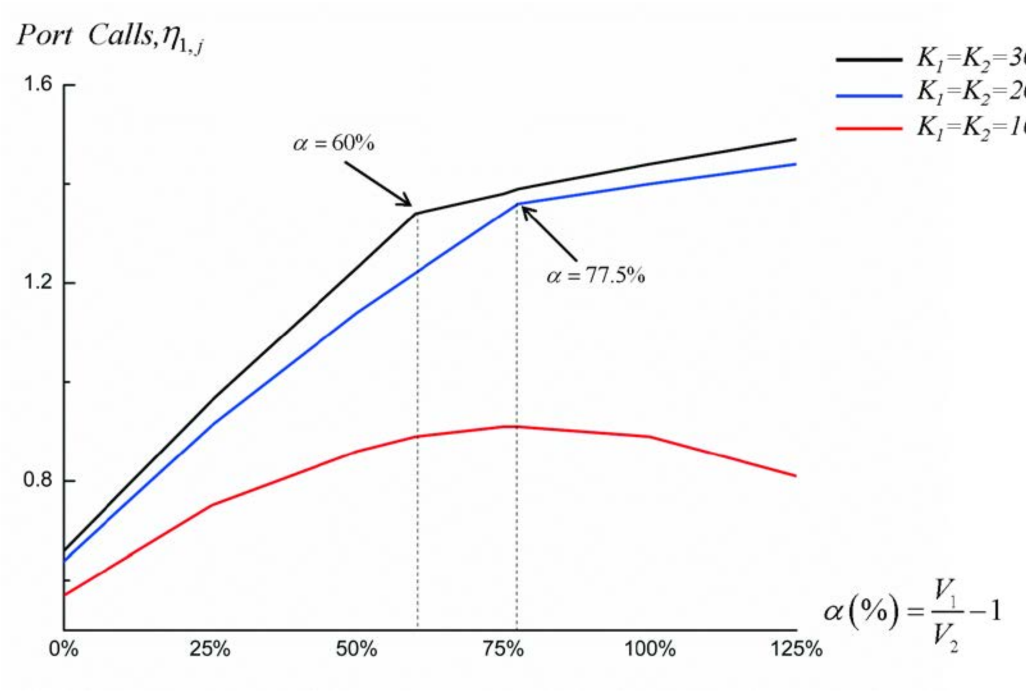


Figure 7 Effect of capacity levels on port call distribution strategies, over basic hinterland demand

Figure 7 shows the shipping lines' ship call distribution strategies for port 1 subjected to differing basic hinterland demand between two equally-sized ports. As expected, a port with a larger capacity will attract more port calls. The difference in the number of port calls attracted when capacity $K_1=K_2= 10$ and capacity $K_1= K_2 =20$ is substantial; yet the difference between the number of port calls attracted when capacity $K_1= K_2=20$ and capacity when $K_1= K_2= 30$ is miniscule by comparison. It implies that port with an inadequate capacity will cause a severe congestion and port calls loss. In addition, while capacity $K_1= K_2 =10$ carried a different slope with others. As a result of the lack of capacity, serious congestion ensues, specifically when port 1's basic hinterland demand is 177.5% or above the basic hinterland demand of port 2, and the frequency of ship calls at port 1 thusly decreases. Similar slopes are obtained when the port capacity is relatively enough (see $K_1= K_2 =20$ and $K_1= K_2 =30$), the frequency of ship calls at port 1 increases as port 1 has a better hinterland. Furthermore, there are two turning pints α =60% and α =77.5% for two port capacity respectively, these points distinguish whether shipping lines dispatch all their ships, or rather shipping lines will not to run all their ships before this turning port ($\eta_{1,j}+ \eta_{2,j}<R$), and they will exhaust their transport capacity to meet their maximum profit after the turning point ($\eta_{1,j}+ \eta_{2,j}=R$). It can be observed that the frequency of ship calls at port 1 carries a gentle slope after shipping lines dispatch all their ships. It can be explained with Figure 8 ($K_1= K_2 =20$), the price of port 2 doesn't change before the turning point α =77.5%, it means there is no competition on ship calls between two ports as supply of ships exceeds demand, thus it's easy for such a port to attract more port calls. However, the competition for port calls occurs when the demand of ships exceeds supply. As shown in Figure 8, the price of port 2 decreases after the turning point α =77.5% to reduce the port call drain. Another important finding is better hinterland will yield a higher port price as expected.

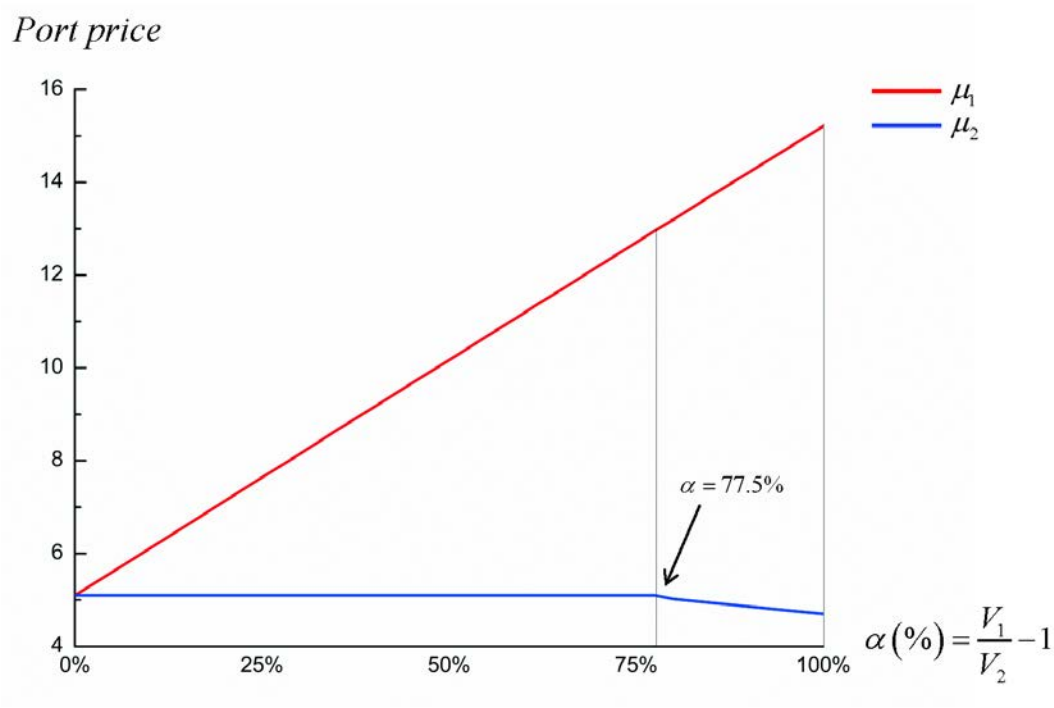


Figure 8 Equilibrium port price over basic hinterland demand

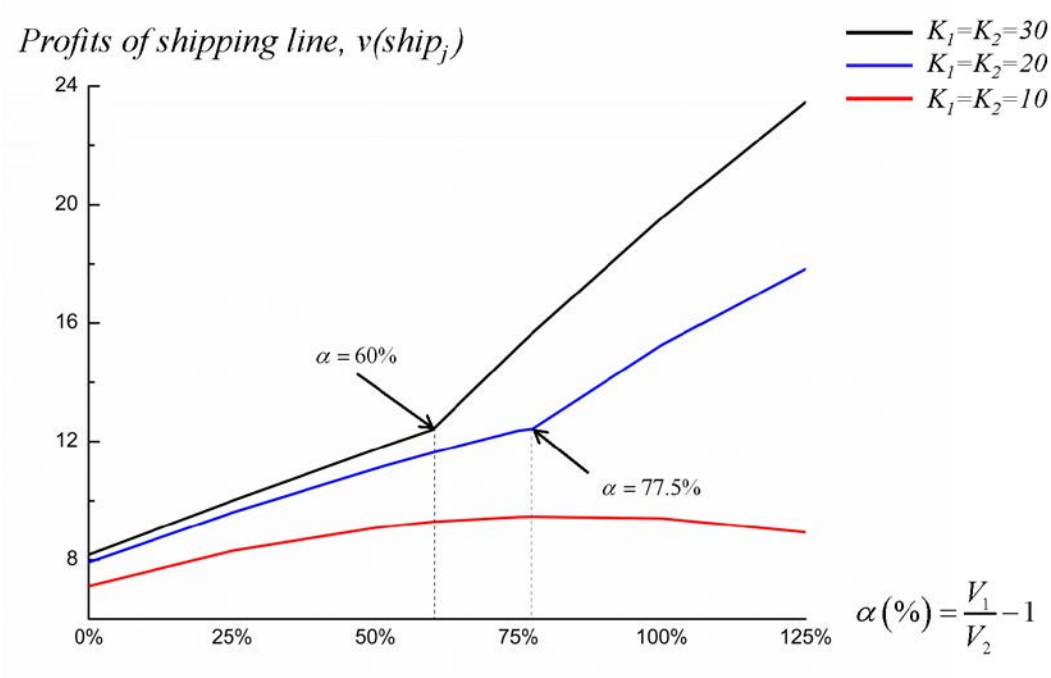


Figure 9 Effect of capacity levels on the profit of shipping lines, over basic hinterland demand

As the results from strategies of shipping lines and ports, the profits of shipping lines are shown in Figure 9. For the poor infrastructure situation ($K_1 = K_2 = 10$), as the port 1's basic hinterland demand increases, shipping lines' profit rise slowly, a slightly downward trend has emerged when α is larger than 100%. This is due to the fact that serious congestion leads to a decrease of the number of ships which shipping lines are willing to run. However, a higher port capacity tells a different story. As the basic hinterland demand of port 1increases; shipping lines obtain more profit, especially when the demand of ships exceeds supply. The upward trend of shipping lines' profits is more significant. It is reasonable to assume that as the demand for ships exceeds the supply, shipping lines inhabit the predominant position in the industry. Thus the profit of shipping lines will grow faster along with the increase of basic hinterland demand.

5.3. Cooperative game

After discussion of the non-cooperative game in shipping industry, the cooperative game and the comparative analysis with respect to the non-cooperative game will be discussed in this section. The cooperative game is a two stage game. In the first stage, shipping lines and ports decide their cooperative strategies based on their predictions. The second stage is modelled as a static game with the coalitions and the others that have not assimilated. It will be discussed in the following two sub-sections respectively. According to the assumption, shipping line N is qualified to cooperate with port, while shipping line j ($j=1, 2,\ldots, N-1$) is not qualified.

5.3.1. Cooperative strategy

In this section, an analysis the cooperative strategy in the first stage game is given. The results of the numerical analysis above show that the status of ships' supply and demand is a key index for analysis of shipping industry. Thus, a shipping line's strategy of port call distribution under different coalition is shown in Figure 10 and Figure 11.

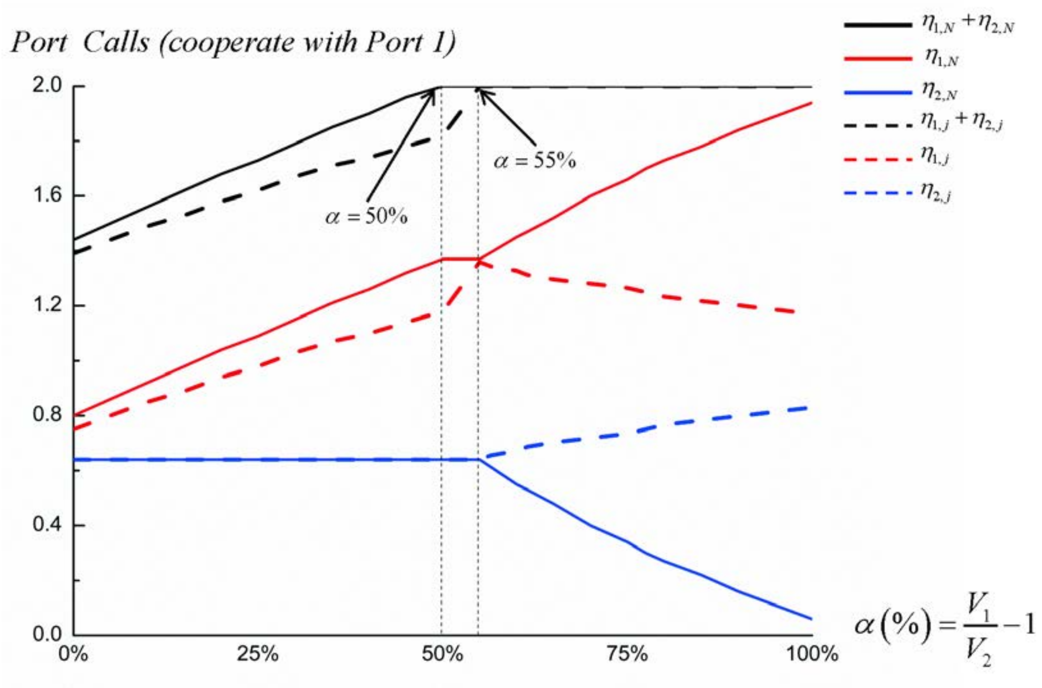


Figure 10 Port call distribution strategies over basic hinterland demand (Coalition of shipping line N and port 1)

Figure 10 shows the shipping lines' port call distribution decision when shipping line N collaborates with port 1. In order to describe this figure, it is important to first note the two turning points, α=50% and α=55% are the critical points that determine whether shipping line N and shipping line j have sent all their ships respectively. To be precise, when α is larger than 50%, shipping line N has exhausted its transport capacity ($\eta_{1,N}+\eta_{2,N}=R$) to pursue the maximum profit of the coalition, while shipping line j will dispatch all its ships when α is larger than 55% ($\eta_{1,j}+\eta_{2,j}=R$). For the case of frequency of ship calls at port 1, as expected, when port 1's basic hinterland demand increases, shipping line N always dispatches more ships to port 1 than shipping line j. However, there are two intervals which are most noticeable. Firstly, the situation that shipping line N dispatches all its ships while shipping line j does not reach its transport limitation (50 %< α<55%), under such circumstances, shipping line j dramatically increases the ships call at port 1while shipping line N almost stops sending more ships to port 1. It can be explained that, although shipping line N reaches its transport limit, the supply of ships still exceeds demand in whole shipping industry. Thus as the basic hinterland demand of port 1increases, shipping line j has extra transport capacity to satisfy the increased demand while it is ineffective for shipping line N to move the ships at port 2 to port 1. Secondly, when all the shipping lines are reaching their transport limits (α>55%), shipping line N begins to rearrange more ships to the port while shipping line j decreases the ship calls at port 1. It can be explained that shipping line j loses the advantages of transport capacity and transfers ships to port 2 will be more profitable again. For the case of port 2, when the supply of ships exceeds demand (α<55%), shipping line N and shipping line j dispatch the same frequency of ship calls to port 2. Furthermore, a better hinterland of port 1 has no influence on the shipping lines' decision of port 2, since there is no competition on ship calls between two ports and port 2 has obtained the maximum ship calls it deserves in this circumstances. However, When demand of ships exceeds supply (α>55%), shipping line N transfers most of ships from port 2 to port 1, while shipping line j slightly increase ship calls at port 2.

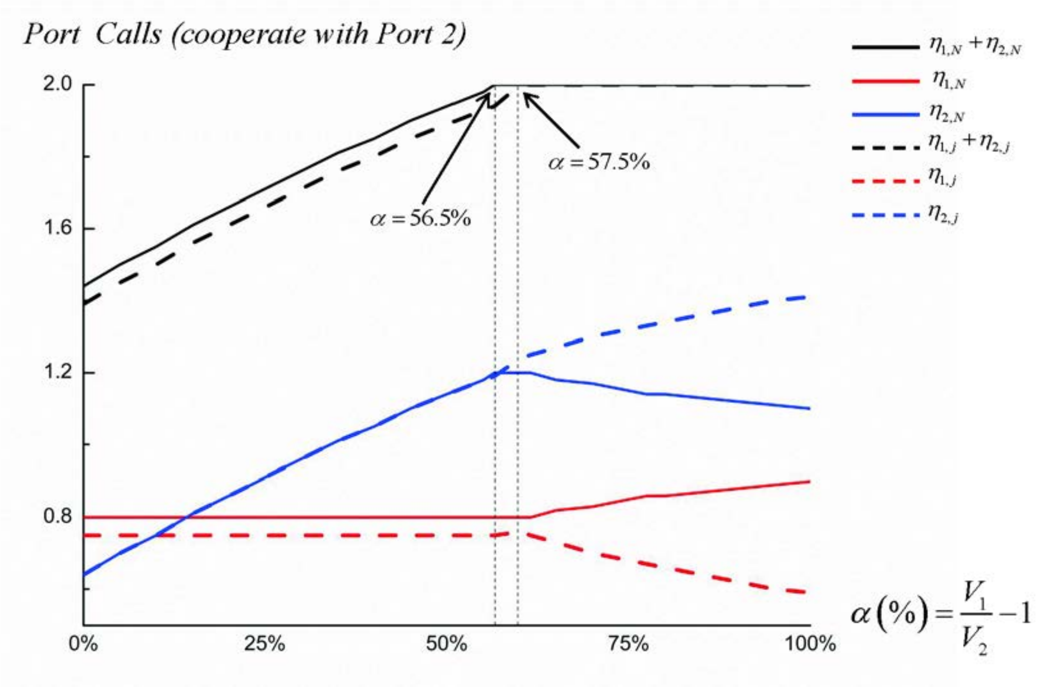


Figure 11 Port call distribution strategies over basic hinterland demand (Coalition of shipping line N and port 2)

Figure 11 shows the shipping lines' port call distribution decisions when shipping line N collaborates with port 2. Similar to the situation of the coalition of shipping line N and port 1 in Figure 10, there are two turning points α=56.5% and α=57.5%. While α=56.5% is the point that shipping line N allocates all its ships and shipping line j doesn't reach its limitation, α=57.5% is the point that both shipping line N and shipping line j dispatch all their ships. For the case of the frequency of ship calls at port 2, shipping line N arranges more ships to port 2 than shipping line j dose, as expected, since shipping line N's objective is maximizing the coalition's profit with port 2. Furthermore, similar to the formation of coalition in Figure 6, when supply of ships exceeds demand (α=56.5%), the increase of port 1's basic hinterland demand doesn't affect the frequency of ship calls at port 2 and port 2 has obtained the highest frequency of ship calls it can attract. When ships become in short supply, shipping line j will transfer large amounts of ships from port 2 to port 1, while shipping line N will still stand for port 2 and slightly increase the quantity of ships to port 2. For the case of port 1, as the basic hinterland demand of port 1 increase, shipping lines are willing to dispatch more ships to port 1 to pursue the profit. When there are excess ships in maritime transport (α<56.5%), identical port call decisions are made by all the shipping lines. However, when ships become a scarce resource in shipping industry (α>56.5%), the opposite decisions are made by shipping line N and ship ping line j, which shipping line j increases the ships to port 1while shipping line N transfers the ships from ships to port 2. It can be understood that when demand of ships exceeds supply, shipping line j transfers large amount of ships to port 1 to meet the increase demand of port 1 which will lead to a substantial profit losses of port 2, in this circumstances, shipping line N has to send more ships to port 2 to maintain the coalition's profit.

After the discussion on the shipping line's strategy of port call distribution under different coalition, the cooperative strategy will be analyzed through the differing coalition profit in the following figure.

5.3.2. **Change in shippers' surplus**

Shippers are the most important and final customers in shipping industry, their surplus decide the rise and decline of international trade as well as shipping industry. Thus the change in shippers' surplus after coalition of shipping line and port deserves much attention. In this section, a discussion of the change in shippers' surplus in different formation of coalition of shipping line and port is provided.

As shown in Figure 12 below, the differing of shippers' surplus is always positive after the coalition of shipping line and port. It implies that the coalition is always beneficial from the perspective of shippers. Furthermore, shippers would prefer the combination of the coalition of shipping line and the port with a better hinterland. Further explanation can be observed from Figure 13, it shows that the coalition decreases the fees charged by the port within the coalition, and it can increase the surplus of shippers who transport from the port in alliance. In this case, although port price falls even more as cooperating to the port with poor hinterland, the amount of cargos transport from the port with good hinterland is larger than the port with poor hinterland.

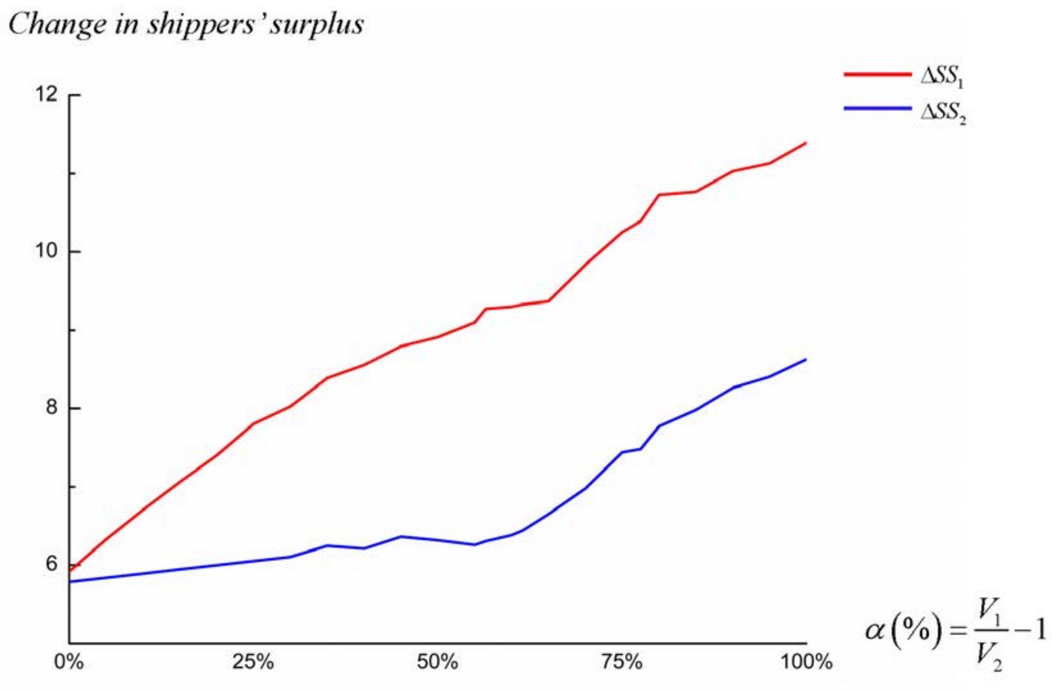


Figure 12 Change in shippers' surplus in different coalition

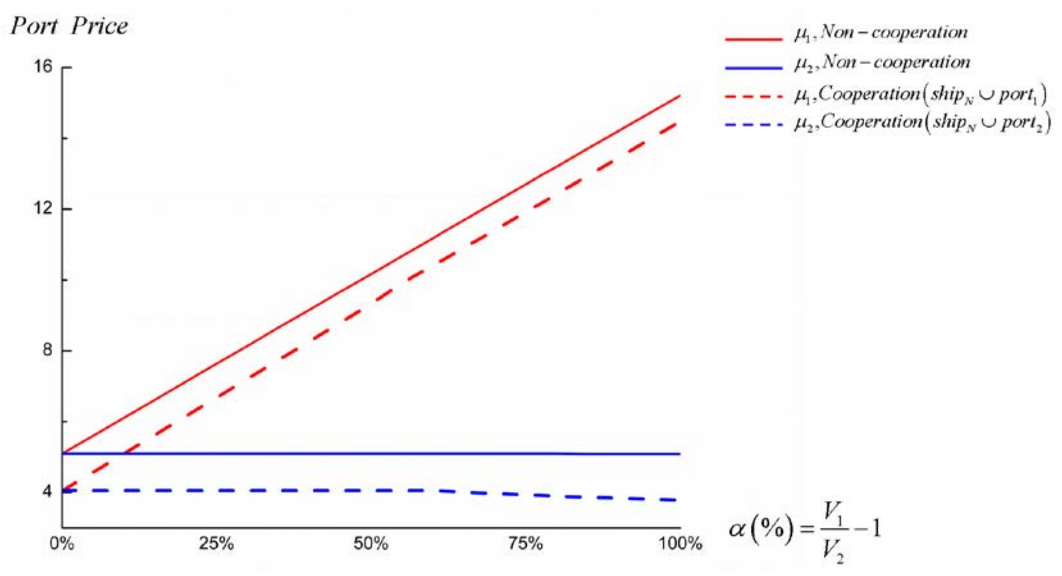


Figure 13 Comparison of port price before and after cooperation

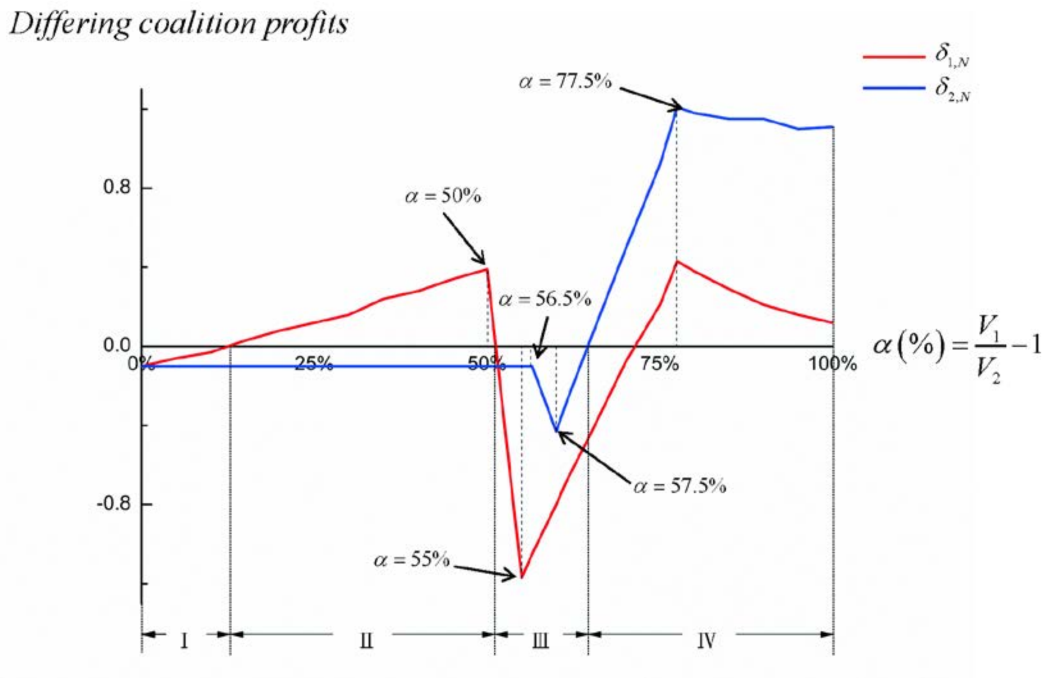


Figure 14 Differing coalition profit in different combination of the coalition over basic hinterland demand

Figure 14 contains analysis of the features of differing coalition profit over basic hinterland demand. It can be observed that the differing coalition profit $\delta_{1,N}$ and $\delta_{2,N}$ have a similar trend over basic hinterland demand. As such, a description of the trend of differing coalition profit in the coalition of shipping line N and port 1 and an analysis of the fundamental reason for this result are provided. For the case of an alliance between shipping line N and port 1, the shipping lines' supply decisions are shown in Figure 10. As such, α=50% and α=55% represent the turning points when shipping line N and shipping line j have sent all their ships respectively. These two turning points can be viewed as links to analyze the following results. When α is less than 50% (that is, the ships' supply exceeds demand) the differing coalition profit $\delta_{1,N}$ increases with a better basic hinterland demand of port 1. However, as the port 1's basic hinterland demand continue to increase, shipping line N firstly reach its transport limit while shipping line j still has extra ships (50%<α<55%), the differing coalition profit drops dramatically. In this situation, shipping line j maintains a more favourable position in the competition, thus leading to a massive loss of the coalition's profit. As expected, when all the ships reach their transport limits (55%<α<77.5%), shipping line N and shipping line j return to their original situation, thus the differing coalition profit $\delta_{1,N}$ increase immediately as port 1's basic hinterland demand increase. However, there is another turning point α=77.5% which is demand of ships exceeds supply even in the non-cooperative game (Figure 7). In this situation, the shipping market experiences a boom, in which shipping lines occupy the stronger position in shipping industry, thus the coalition's advantage is watered down.

This part of the paper will deal with the cooperative strategy in the first game stage. As shown in Figure 14, in phase I and III, it can be noticed that the differing coalition profit is negative. It does not satisfy the superadditive property, which means at least one player can get a better payoff by working alone. Thus they will act independently in these two phases. In phase I, two ports have similar hinterland demand and ships supply far outstrips demand, it implies that there is no motivation for the formation of a coalition between shipping line and port as the situation of the serious shortage of maritime transportation demand. In phase III, as the shipping demand slightly exceeds supply, the coalition will also incur a loss of profits. It implies that when shipping lines and ports are all in a relative powerful position alongside the situation that the differing of basic hinterland demand between port 1 and port 2 is not significant, there is no motivation for shipping lines and ports to cooperate. Furthermore, in phase II, it is obtained that the coalition of shipping line N and port 1 yields a higher profit than the case without cooperation ($\delta_{1,N}$>0), it implies that shipping lines are more willing to cooperate with a port with a better hinterland during a shipping recession. In phase IV, the coalition of shipping line N and port 2 obtains higher profit than the non-cooperation case, and it's also a better alliance than the coalition between shipping line N and port 1($\delta_{2,N}$>0 and $\delta_{2,N}$>$\delta_{1,N}$). It indicates that shipping lines will form an alliance with the port with a poor hinterland during a shipping bloom. Further explanations can be observed that port 1 occupies the dominant position in the competition with port 2, thus port 1 is so powerful in the shipping market that the profits will be squeezed by it. In this condition, the coalition of shipping line N and port 2 can maintain the balance of market power in shipping industry.

5.3.3. The best strategy in the cooperative game

Based on the cooperative strategy above, the best alliance strategies for shipping line N is to cooperate with Port 1 in phase II, to cooperate with Port 2 in phase IV and not to cooperate with any port in phase I and III. Then the best strategy in cooperative game will be discussed in the following. As shown in the Figure 15 to Figure 19, solid lines express the results without cooperation, and dashed lines represent the trend after the cooperation.

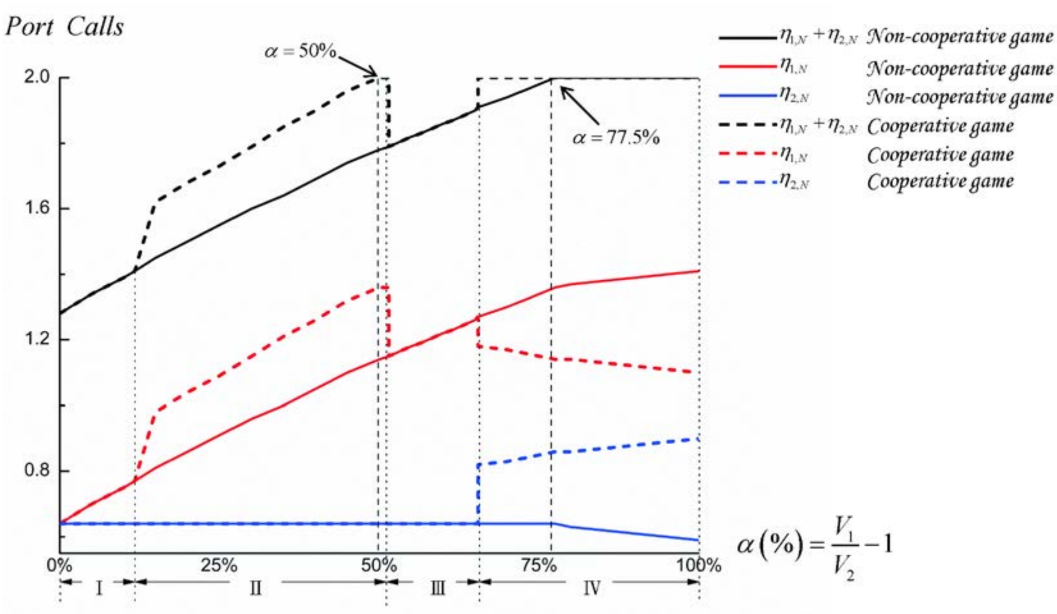


Figure 15 Shipping line N's port call distribution over basic hinterland demand

Figure 15 displays shipping line N's port call distribution over basic hinterland demand. In phase I and III, since shipping line N will not cooperate with any port, the numbers of ships it put in the ports does not change compared with the number of non-cooperative game. In phase II, shipping line N begins to cooperate with Port 1. As a result of this, more ships will be allocated in Port 1than the case of non-cooperative game, as the supply of ships exceeds the demand for ships and Port1 and Port 2 do not have to compete for ships; the frequency of ship calls at Port 2 remains the same. In phase IV, shipping line N starts to form a coalition with Port 2. As expected, port 2 obtains more ships than the case of non-cooperation. Furthermore, as the basic hinterland demand increases, the demand for ships massively exceeds supply in phase IV. Thus shipping line N has to transfer some of the ships from Port 1 to Port 2. So the frequency of ship calls at Port 1 decreases after the coalition of shipping line N and port 2.

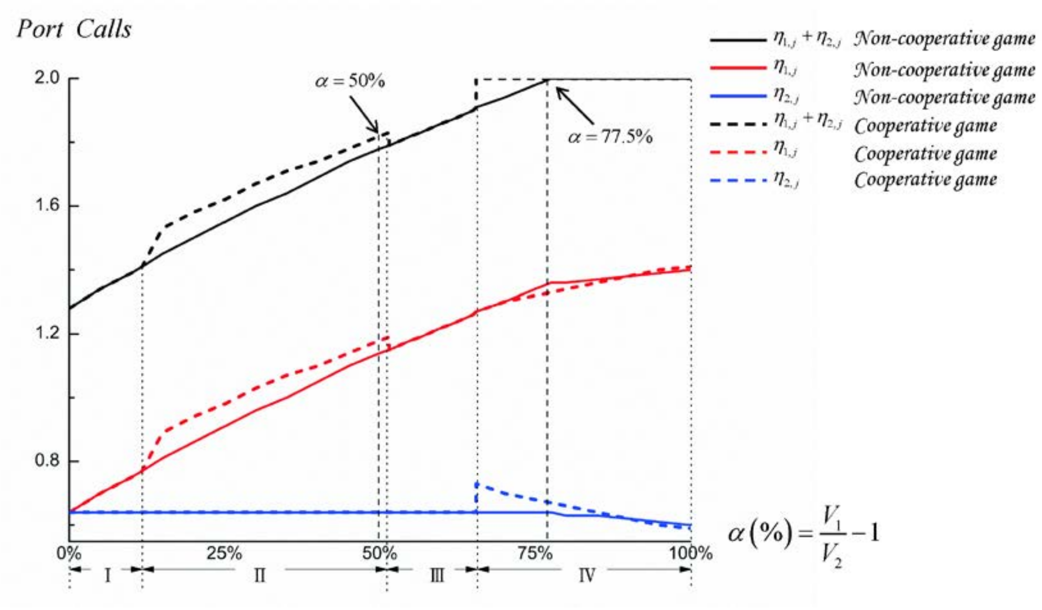


Figure 16 Shipping line j's port call distribution over basic hinterland demand

Figure 16 shows the port call distribution strategy of shipping lines j. similar to Figure 15, in phase I and III, no cooperation exists between ports and shipping lines. The strategy of port call distribution is the same with those of non-cooperative game. However, in phase II, shipping line N begins to cooperate with Port 1. Influenced by this coalition, the number of ships shipping line j arranges to Port 1 also increases compared with the case of non-cooperation. The same phenomenon happens in phase IV when the shipping line begins cooperation with Port 2. It can be explained by the port price, as shown in Figure 17, when shipping line N forms coalition with port 1in phase II, port 1 decreases the price compare to the case of non-cooperation. Similarly, port 2 decreases its price in phase IV. It implies that cooperation leads to a decrease of the fees charged by port within the coalition. However, it has little influence to the port price which acts independently or rather, the port which has cooperated with shipping line will decrease the price to attract more ship calls.

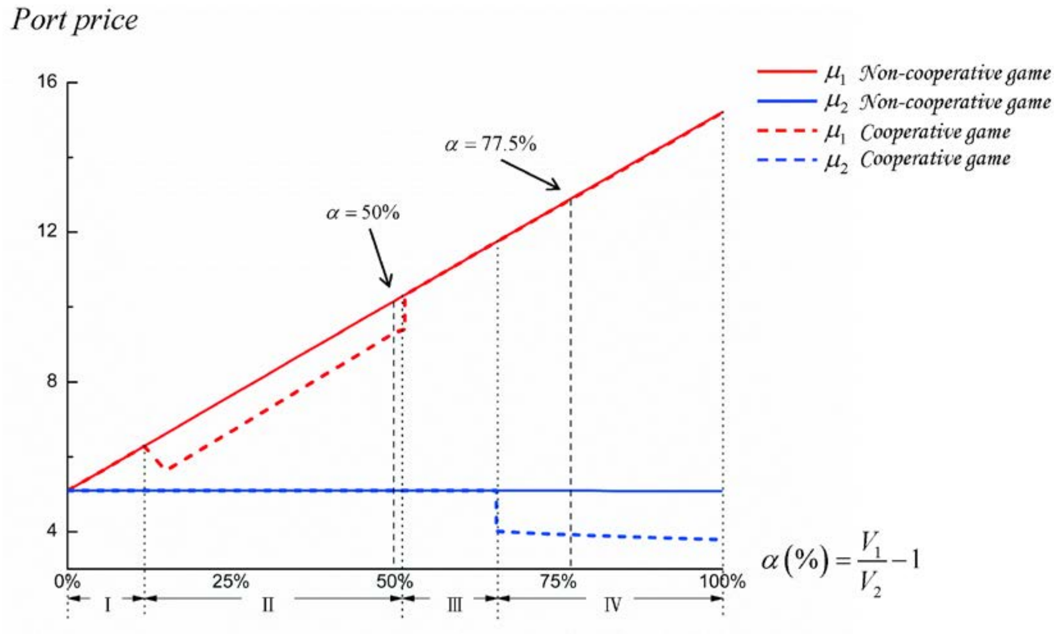


Figure 17 port prices over basic hinterland demand

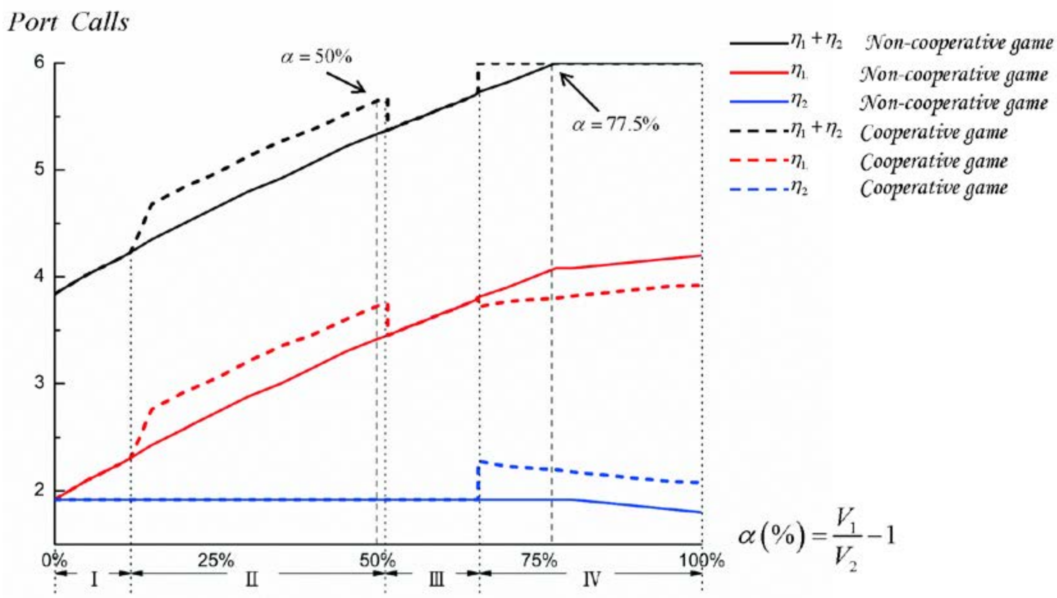


Figure 18 Ship calls at each port over basic hinterland demand

The total ship calls of each port is represented in Figure 18, it is the combination of the port call distribution choice of shipping line N and shipping line j. It has a similar trend as the shipping line N's distribution of port calls due to this cooperation. As such, more ships are needed in this shipping industry. The limitation of ships occurs earlier than the case of non-cooperation. According to Figure 18, the cooperation raises the number of ships in the port which are in coalition with a shipping line in phase II and in phase IV. In phase II, the shipping line increased the ships to port 1; a comparison is given between the co-operative and non- cooperative game. This however, did not change the distribution of port calls at port 2. This is due to the fact that the supply of ships exceeds the demand, thus there exists no competition for port calls. In phase IV, the coalition of the shipping line and port 2 results in the demand of ships exceeding supply, thus there is competition for port calls. Therefore the shipping lines transfer their ships from port 1 to port 2; in direct comparison to the non-cooperative game.

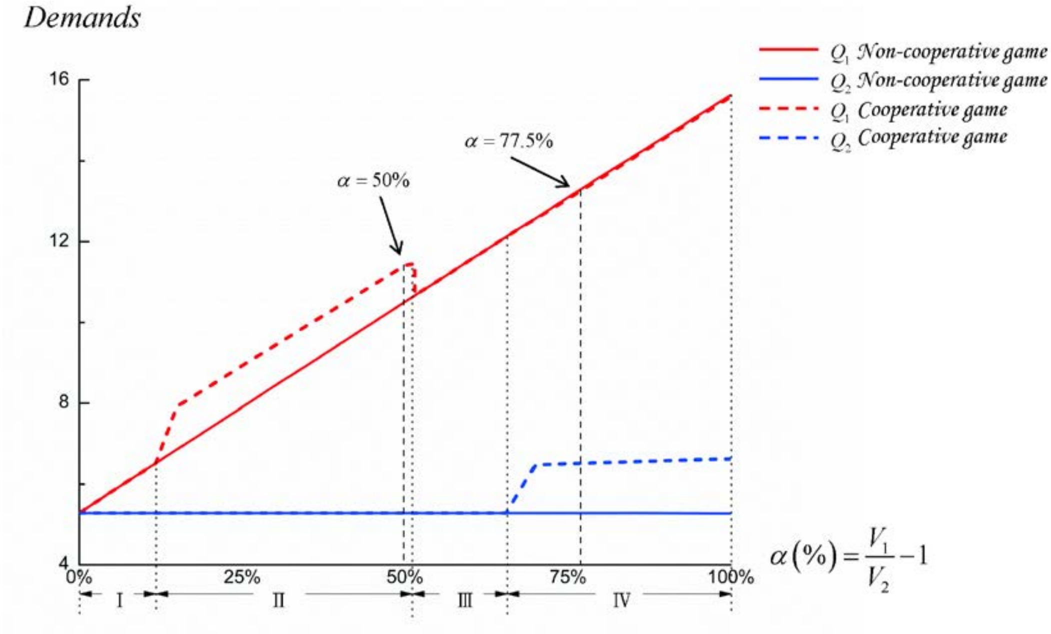


Figure 19 Cargo handling demand of each port over basic hinterland demand

Figure 19 displays the total handling demand of the ports, the trends corresponds to the port price in Figure 17. The decrease of Port 1's price attracts more ship calls and cargo handling demand in phase II than the case of non-cooperation. Meanwhile, the cooperation doesn't affect port 2's cargo handling demand. Similarly, port 2 obtains more handling demand than those of non-cooperative game by decreasing price in phase IV. There is another significant result that the cooperation increases the total cargo handling demand of two ports. Further explanations can be observed that cooperation decreases the fees charged by ports, enabling access for more cargo.

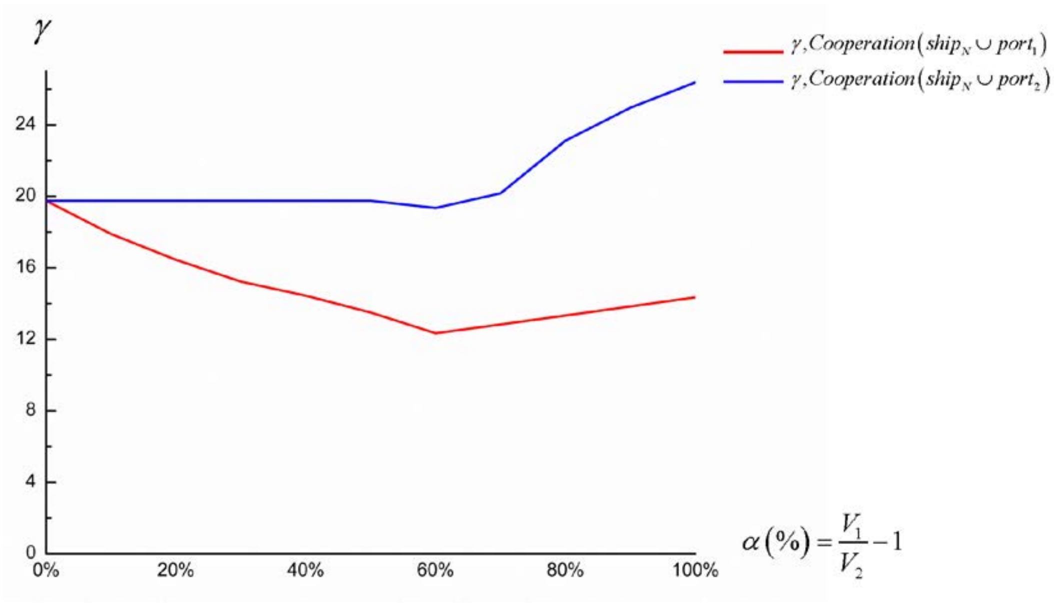


Figure 20 γ in different formation of coalition over basic hinterland demand

According to the Appendix 2, $\gamma > 0$ guarantee the *v(ship$_j$)* is strictly jointly concave in $\eta_{1,j}$ and $\eta_{2,j}$. As shown in Figure 20, γ is always above zero.

6. Application of Busan Port and Shanghai Port

6.1. Introduction

In empirical analysis, an application of the case of Shanghai Port and Busan Port is provided. Busan Port is one of the biggest ports in Northeast Asia. It carries nearly 90% of the total volume of South Korea's international trade transport every year. Shanghai Port is the biggest ports in the world. Almost all of the cargoes from Yangtse River Delta and Yangtse River valley China have to be transported from Shanghai Port.

In this case, a comparison of the condition of Shanghai Port and Busan Port is given. This is followed by an evaluation of the status of the supply of global shipping capacity. Applying the data to the model; several interesting observations are observed.

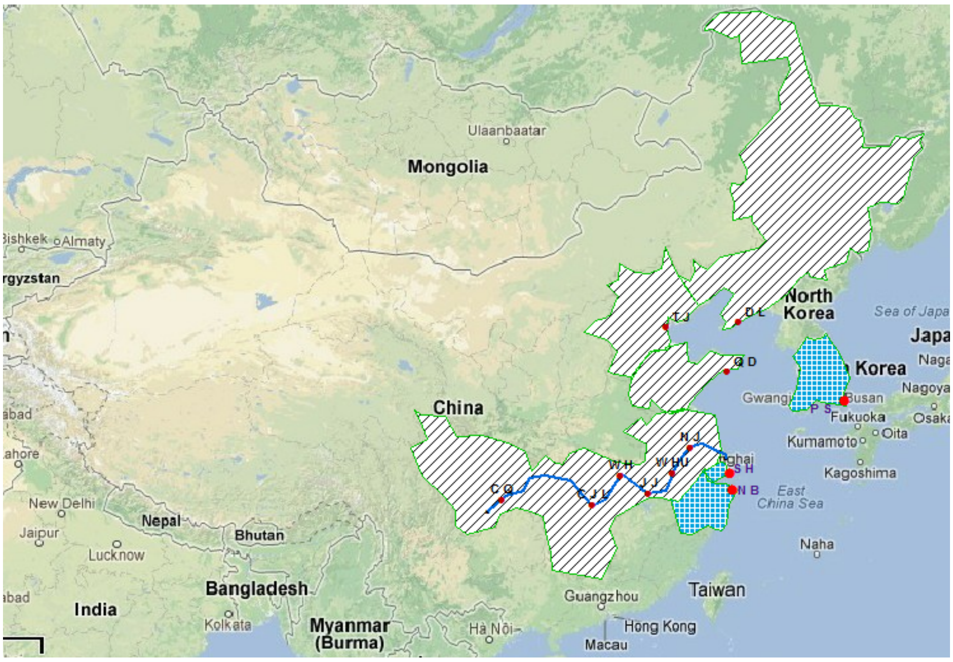


Figure 21 geographical position and hinterland of Shanghai and Busan ports

6.2. Data collection

Given the model in use, the data required is both ports' basic hinterland demand, capacity and the maritime container transportation capacity. This will now be discussed respectively in the following paragraphs.

First, the value of import and export in each port's hinterland is considered as the port's basic hinterland demand. Shanghai port's hinterland is Yangtse River Delta and the Yangtse River valley, nearly all the cargoes have to be transported from Shanghai Port in 2008. However, the opening of the Hangzhou Bay Bridge in October 11, 2008 expands the hinterland of Ningbo Port. Shippers in Zhejiang Province are more likely to opt for Ningbo Port due to the shortened route via the bridge (Business Alert- China, 2008). It is considered that the Zhejiang Province is one of the hinterland of Shanghai Port 2008, while this was not so in 2013. Busan Port occupies a dominant position in South Korea, carrying nearly 90% of the total international trade of South Korea every year, according to Korean custom's official site, it can be considered that the entirety of South Korea as the hinterland of Busan Port. Based on the above statement, the basic hinterland demand of Shanghai and Busan of 2008 and 2013 is obtained. (See Appendix 3)

Table 13 The volume of import and export of Shanghai and Busan ports

	2013		2008	
	Busan	Shanghai	Busan	Shanghai
Volume of international trade (Export and Import)（Billion $）	1075.2	1255.8	857	1031.52

Second, the cargo handling capacity of each port from their official sites is obtained. As several new terminals have been completed in this time, the capacity of ports has increased slightly. According to the completion data of the terminals, it is considered that the capacity of two ports in 2008 and 2013 somewhat increased (see Appendix 4).

Table 14 The port capacity of Shanghai and Busan ports

	2013		2008	
	Busan	Shanghai	Busan	Shanghai
Cargo handling Capacity (Million TEU)	12.71	17.66	9.1	12.66

Third, the maritime container transportation capacity of the world is collected. In order to evaluate the limitation of port calls in Shanghai and Busan ports' competitive market, it is considered that the limitation of maritime container transportation capacity, in this competitive market, is proportional to Northeast Asia's share of the global volume of imports and exports. (See Appendix 5)

Table 15 The carrier capacity of container fleet

	2013		2008	
	Busan	Shanghai	Busan	Shanghai
Total volume of trade (Export and Import) Northeast China and South Korea（Billion $）	3752.27		2563.07	
Volume of global trade(Export and Import) (Billion $)	12902.4		10284.48	
Global container shipping capacity (Million TEU）	17.14		13.03	
Computed total container shipping capacity of Northeast China and South Korea (Million TEU)	4.98		3.25	

Source: (PLC Clarkson, 2014)

Using the same parameters as before: d_1=1, d_2=0.1, $S=13$, $P=10$, $c=2$, $N=3$, $R=2$, $\beta=3$. To standardize the data, the carrier capacity of each container fleet is set as $R=2$, Busan port's basic hinterland demand as $V_2=25$ and cargo handling capacity as $K_2=10$ in 2013. In accordance with the data collected, the standardized data of Shanghai and Busan ports in the created model is listed as follow:

Table 16 Normative data of shipping line and port

	2013		2008	
	Busan	Shanghai	Busan	Shanghai
Basic hinterland demand	25	29.2	19.93	23.98
Cargo handling capacity	10	13.89	7.16	9.96

Carrier capacity of each container fleet	2	2	1.3	1.3

Table 17 Profit of shipping lines and ports for different combinations of coalitions in 2008

Profits and Port calls of each case									
	$\eta_{1,N}+\eta_{2,N}$	$\eta_{1,j}+\eta_{2,j}$	*SLj*	*SL_N*	*P1*	*P2*	*Combined Profit*	*C.P. Before*	*Increased C.P.*
Case A: All players are independent	**1.24**	**1.24**	**7.76**	**7.76**	**50.38**	**25.42**			
Case B: (SL_N +P1) and P2 is independent	**1.3**	**1.3**	**7.57**	**7.56**	**50.16**	**25.43**	**57.72**	**58.14**	**-0.42**
Case C: (SL_N +P2) and P1 is independent	**1.3**	**1.26**	**7.83**	**8.08**	**50.38**	**25.15**	**33.23**	**33.18**	**0.05**

In case B, shipping line N and Shanghai Port have formed a coalition. The joint profit of shipping line N and Shanghai Port, shown in Table 1, is 0.42 lower than that of the case in which shipping lines and ports work independently. Hence this combination does not satisfy the superadditive property of the characteristic function. The formation of this coalition is not possible because at least one player can get receive an increased payoff.

In case C, shipping line N cooperates with Busan Port. The total joint profit is 0.05 higher than the case of no cooperation. Hence this combination satisfies the superadditive property. As a consequence of this, shipping line N is more willing to cooperate with Busan Port in 2008.

Table 18 Profit of shipping lines and ports for different combinations of coalitions in 2013

Profits and Port calls of each case									
	$\eta_{1,N}+\eta_{2,N}$	$\eta_{1,j}+\eta_{2,j}$	*SLj*	*SL_N*	*P1*	*P2*	*Combined Profit*	*C.P. Before*	*Increased C.P.*
Case A: All players are independent	**1.74**	**1.74**	**11.01**	**11.01**	**95.04**	**57.95**			
Case B: (SC_N +P1) and P2 is independent	**1.91**	**1.75**	**10.65**	**11.56**	**94.82**	**57.95**	**106.38**	**106.05**	**0.33**
Case C: (SC_N +P2) and P1 is independent	**1.85**	**1.76**	**10.85**	**11.39**	**95.04**	**57.74**	**69.13**	**68.96**	**0.17**

In case B, shipping line N and Shanghai Port have formed a coalition. The increased joint profit of shipping line N and Shanghai Port, shown in Table 1, is 0.33 higher than that of the case in which shipping lines and ports work independently, which is 0.16 higher than that of Case C. Hence shipping line N is more willing to cooperate with Shanghai Port in 2013.

7. Conclusions

In response to fierce competition of container cargo transportation markets, cooperation has become the mainstream of this era. Consolidation of shipping routes, globalization of shipping lines and cooperation of port operators have emerged. This paper adopts a game theory approach to modelling consolidation of shipping lines and ports, and establishes a two-stage game scenario with two ports and multiple shipping lines. In the first stage, shipping lines and ports decide their cooperative strategies based on their prediction. The second stage is modelled as a static game with the coalition and the others that have not joined the coalition. Three possible combinations of alliances are investigated. Numerical analysis is conducted to obtain the best strategies of shipping lines and ports.

The results show that the cooperation strategy of shipping lines strongly depends on the supply and demand situation of ships. The port which collaborates with shipping lines will have a significant decrease in port charges, which h creates an advantage of gaining more port calls and demand, but it will have a limited effect on the charge of the other port. The cooperation may result in a loss to the port, thus reallocation of profit is needed to maintain the coalition. In addition, shippers can obtain more surpluses in the case of cooperation between shipping line and port. Shippers would prefer the coalition of the collaboration of shipping line and the port with better hinterland.

According to the numerical analysis of non-cooperative game, it is found that the port capacity is similarly important to the basic hinterland demand. If the port capacity is woefully inadequate, the better basic hinterland may lead, instead, to a decrease in ship calls of port. Thus, the port's infrastructure should fit into the cargo handling demand.

In relation to the cooperative game, analysis provides that the cooperative strategy mainly depends on the status of ships' supply and demand. When the ships' supply exceeds demand and the two ports have a similar status of the hinterland, it is more profitable for all players to act independently. However, if a port has a decisive advantage in hinterland demand alongside the situation when the ships' supply exceeds demand, a shipping line should cooperate with the dominant port. When the ships' demand exceeds supply slightly, then the shipping line's best strategy is also to act as a single entity. When the demand for ships far outstrips the supply and the port has a substantial disadvantage in hinterland demand, the shipping line should cooperate with the weaker port.

Additionally, the cooperation between shipping lines and ports will result in shipping lines dispatching more ships than the situation of non-cooperative game. Furthermore, cooperation leads to a decrease of the port price.

Further research

Considered as a breakthrough in this field, this research can be further expended to several directions. The first one is the complement of the scenarios of game theory. Since only one scenario is studied in this research, more scenarios may be applied in future researches. For instance the scenario in this research allows only one shipping line to cooperate and only one port can be chosen to be the partner. However in future research, a multi-player cooperation scenario can be discussed. Secondly, since only financial aspect is considered in this research, the measurement on how the factors, such as long-term relationship, environmental consideration or governmental regulation, influence this type of cooperation can be investigated. Third, given the appearance of predominant shippers in the shipping market, the cooperation between shipping lines and predominant shippers may be a topic of high practical value to be studied.

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Appendix

1. Proof of lemma 1

Taking the first-order partial derivatives of $v(ship_j)$ with respect to $\eta_{1,j}$ and $\eta_{2,j}$,we have,

$$\frac{\partial v(ship_j)}{\partial \eta_{i,j}} = -2d_2 D_i \frac{\eta_{i,j}}{\eta_i} - Q_i D_i \frac{\eta_i - \eta_{i,j}}{\eta_i^2} + (P-c) d_2 \frac{\eta_{i,j}}{\eta_i} + (P-c) Q_i \frac{\eta_i - \eta_{i,j}}{\eta_i^2} - S,\ i = 1,2.$$

Taking the second-order partial derivates with respect to $\eta_{1,j}$ and $\eta_{2,j}$, we can obtain:

$$\frac{\partial^2 v(ship_j)}{\partial \eta_{i,j}^2} = -2d_2^2 \frac{\beta}{K_i} \frac{\eta_{i,j}}{\eta_i} + 2\left[d_2\eta_i (P-c-2D_i) - Q_i (P-c-D_i)\right] \frac{\eta_i - \eta_{i,j}}{\eta_i^3}$$

We assumed $V_i - d_1\mu_i \geq 0$, then $Q_i = V_i - d_1\mu_i + d_2\eta_i \geq d_2\eta_i$.

$$\frac{\partial^2 v(ship_j)}{\partial \eta_{i,j}^2} \leq -2d_2 \frac{\beta}{K_i} \frac{\eta_{i,j}}{\eta_i} + 2\left[d_2\eta_i (P-c-2D_i) - d_2\eta_i (P-c-D_i)\right] \frac{\eta_i - \eta_{i,j}}{\eta_i^3}$$

$$= -2d_2 \frac{\beta}{K_i} \frac{\eta_{i,j}}{\eta_i} - 2d_2\eta_i D_i \frac{\eta_i - \eta_{i,j}}{\eta_i^3} < 0.$$

$$\frac{\partial^2 v(ship_j)}{\partial \eta_{1,j} \partial \eta_{2,j}} = \frac{\partial^2 v(ship_j)}{\partial \eta_{2,j} \partial \eta_{1,j}} = 0.$$

Thus the Hessian matrix is negative definite at $\eta_{1,j}$ and $\eta_{2,j}$, therefore $v(ship_j)$ is strictly jointly concave in $\eta_{1,j}$ and $\eta_{2,j}$.

2. Proof of lemma 2

Taking the first-order partial derivatives of $v(ship_N \cup port_i)$ with respect to $\eta_{1,N}$,$\eta_{2,N}$, and μ_i, we have,

$$\frac{\partial v(ship_N \cup port_1)}{\partial \eta_{1,N}} = -2d_2 D_1 \frac{\eta_{1,N}}{\eta_1} - Q_1 D_1 \frac{\eta_1 - \eta_{1,N}}{\eta_1^2} + (P-c) d_2 \frac{\eta_{1,N}}{\eta_2} + (P-c) Q_1 \frac{\eta_1 - \eta_{1,N}}{\eta_2^2} - S + d_2\mu_1$$

$$\frac{\partial v(ship_N \cup port_1)}{\partial \eta_{2,N}} = -2d_2 D_2 \frac{\eta_{2,N}}{\eta_2} - Q_2 D_2 \frac{\eta_2 - \eta_{2,N}}{\eta_2^2} + (P-c) d_2 \frac{\eta_{2,N}}{\eta_2} + (P-c) Q_2 \frac{\eta_2 - \eta_{2,N}}{\eta_2^2} - S$$

$$\frac{\partial v(ship_N \cup port_1)}{\partial \mu_1} = -d_1 \left(\frac{2d_1\beta\eta_{1,N}}{K_1\eta_1} + 2\right)\mu_1 + \left(\frac{2d_1\beta\eta_{1,N}}{K_1\eta_1} + 1\right)(V_1 - d_1 P + d_2\eta_1) - d_1 (P-c) \frac{\eta_{1,N}}{\eta_1}$$

Taking the second-order partial derivatives with respect to $\eta_{1,N}$, $\eta_{2,N}$ and μ_1,

$$\frac{\partial^2 v(ship_N \cup port_1)}{\partial \eta_{1,N}^2} < 0,$$

$$\frac{\partial^2 v\left(ship_N \cup port_1\right)}{\partial \eta_{2,N}{}^2} < 0,$$

$$\frac{\partial^2 v\left(ship_N \cup port_1\right)}{\partial \mu_1{}^2} = -d_1\left(\frac{2d_1\beta\eta_{1,j}}{K_1\eta_1} + 2\right) < 0,$$

$$\frac{\partial^2 v\left(ship_N \cup port_1\right)}{\partial \eta_{2,N}\partial \eta_{1,N}} = \frac{\partial^2 v\left(ship_N \cup port_1\right)}{\partial \eta_{1,N}\partial \eta_{2,N}} = 0,$$

$$\frac{\partial^2 v\left(ship_N \cup port_1\right)}{\partial \eta_{2,N}\partial \mu_1} = \frac{\partial^2 v\left(ship_N \cup port_1\right)}{\partial \mu_1\partial \eta_{2,N}} = 0$$

$$\frac{\partial^2 v\left(ship_N \cup port_1\right)}{\partial \eta_{1,N}\partial \mu_1} = \frac{\partial^2 v\left(ship_N \cup port_1\right)}{\partial \eta_{1,N}\partial \mu_1} = 2d_1d_2\frac{\beta}{K_1}\frac{\eta_{1,N}}{\eta_1} + d_1\frac{\eta_1 - \eta_{1,N}}{\eta_1}\left(2D_1 - P + c\right) + d_2$$

Apparently, in order to guarantee the negative definite of hessian matrix of $v\left(ship_N \cup port_1\right)$, we need to obtain the determinant of hessian matrix is negative

$$\varphi = \begin{vmatrix} \frac{\partial^2 v\left(ship_N \cup port_1\right)}{\partial \eta_{1,N}{}^2} & 0 & \frac{\partial^2 v\left(ship_N \cup port_1\right)}{\partial \eta_{1,N}\partial \mu_1} \\ 0 & \frac{\partial^2 v\left(ship_N \cup port_1\right)}{\partial \eta_{2,N}{}^2} & 0 \\ \frac{\partial^2 v\left(ship_N \cup port_1\right)}{\partial \eta_{1,N}\partial \mu_1} & 0 & \frac{\partial^2 v\left(ship_N \cup port_1\right)}{\partial \mu_1{}^2} \end{vmatrix}$$

Notating $\gamma = \frac{\partial^2 v\left(ship_N \cup port_1\right)}{\partial \eta_{1,N}{}^2}\frac{\partial^2 v\left(ship_N \cup port_1\right)}{\partial \mu_1{}^2} - \frac{\partial^2 v\left(ship_N \cup port_1\right)}{\partial \eta_{1,N}\partial \mu_1}\frac{\partial^2 v\left(ship_N \cup port_1\right)}{\partial \eta_{1,N}\partial \mu_1}$.

According to $\frac{\partial^2 v\left(ship_N \cup port_1\right)}{\partial \eta_{2,N}{}^2} < 0$, then $\gamma > 0$ is the sufficient condition to guarantee $\varphi<0$ and Hessian matrix is negative definite in the numerical test.

Table 19 Basic hinterland demand of Shanghai and Busan ports

<table>
<tr><td colspan="5">Basic hinterland demand (Billion $)</td></tr>
<tr><td colspan="3"></td><td>2008</td><td>2013</td></tr>
<tr><td rowspan="10">Shanghai</td><td rowspan="3">Yangtse River Delta</td><td>Jiangsu Province</td><td>392.27</td><td>537.36</td></tr>
<tr><td>Shanghai municipality</td><td>322.1</td><td>441.23</td></tr>
<tr><td>Zhejiang Province</td><td>211.15</td><td>-</td></tr>
<tr><td rowspan="6">Yangtse River Valley</td><td>Anhui Province</td><td>28.3</td><td>45.63</td></tr>
<tr><td>Jiangxi Province</td><td>13</td><td>36.74</td></tr>
<tr><td>Hubei Province</td><td>20.57</td><td>36.39</td></tr>
<tr><td>Hunan Province</td><td>12.5</td><td>25.16</td></tr>
<tr><td>Chongqing municipility</td><td>9.52</td><td>68.7</td></tr>
<tr><td>Sichuan Province</td><td>22.11</td><td>64.59</td></tr>
<tr><td colspan="2">Total</td><td>1031.52</td><td>1255.8</td></tr>
<tr><td>Busan</td><td colspan="2">South Korea</td><td>857.04</td><td>1075.2</td></tr>
</table>

Souce: General Administration of Customs of the People's Republic of China, 2014

Table 20 Cargo handling capacity of Shanghai and Busan ports

<table>
<tr><td colspan="8">Cargo handling Capacity (Million TEU)</td></tr>
<tr><td rowspan="8">Busan</td><td>Gamcheon</td><td colspan="2">0.34</td><td rowspan="8">Shanghai</td><td>WuSong Area</td><td colspan="2">2.01</td></tr>
<tr><td>Hutchison</td><td colspan="2">1.2</td><td rowspan="4">Waigaoqiao Area</td><td>Pudong</td><td>1.35</td></tr>
<tr><td>New Singamman</td><td colspan="2">0.65</td><td>Zhendong</td><td>2.5</td></tr>
<tr><td>Singamman</td><td colspan="2">1.2</td><td>Shanghai East</td><td>1.8</td></tr>
<tr><td>Shinsundae</td><td colspan="2">1.28</td><td>Mingdong</td><td>0.7</td></tr>
<tr><td rowspan="2">Busan New Port</td><td>Project 1</td><td>4.43</td><td rowspan="2">Yangshan Deepwater</td><td>Shengdong</td><td>4.3</td></tr>
<tr><td>Project 2 (2011)*</td><td>3.61</td><td>Guandong (2009)**</td><td>5</td></tr>
<tr><td>Total</td><td colspan="2">12.71</td><td>Total</td><td colspan="2">17.66</td></tr>
</table>

* Project 2 of Busan New Port was completed in 2011. Thus it should not be included in the capacity of 2008.
** Guandong of Yangshan Deepwater Port was completed on 31th Dec, 2008. Thus we excluded this part in the capacity of 2008.

Source: SIGP, 2013; Busan port Authority, 2014.

Table 21 The volume of international trade of Northeast east of China and South Korea

Volume of international trade (Billion $)		
	2008	2013
Jiangsu Province	392.27	537.36
Shanghai municipality	322.1	441.23
Zhejiang Province	211.15	335.85
Anhui Province	28.3	45.63
Jiangxi Province	13	36.74
Hubei Province	20.57	36.39
Hunan Province	12.5	25.16
Chongqing municipility	9.52	68.7
Sichuan Province	22.11	64.59
Shangdong Province	158.1	267.1
Shangxi Province	14.39	15.8
Tianjin municipality	80.54	128.53
Hebei Province	38.42	54.88
Beijing municipality	271.71	429.1
Liaoning Province	72.44	114.28
Heilongjiang Province	22.9	38.88
Jilin Province	13.3	25.85
Neimenggu Province	2.71	11
South Korea	857.04	1075.2
total	2563.07	3752.27

Source: General Administration of Customs of the People’s Republic of China, 2014