STUDIES ON PORT COMPETITION, COOPERATION AND INTEGRATION

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Abstract

As an indispensable mode of transportation, maritime transportation has a powerful and profound influence on the global logistics and supply chain network in recent decades. Ports, especially container ports, act as the nodes connecting land and water transportation and play pivotal roles in global logistics network. With the rapid development of international trade and the decentralization of production areas, the freight volume keeps increasing, which also intensifies port competition in practice. Therefore, how to integrate port resources and adopt appropriate strategies (competition, cooperation, integration) are of great significance on both port management and government policies. From the port operation perspective, improving competitiveness is a must to attract both investors and customers, and to be successful in today's competitive environment. From social point of view, having an efficient and competitive port system is very important not only for the commodity trade of that country, but also for the economic development in port cities. Therefore, this thesis attempts to this important problem from following three aspects.

First, the relationships among port competition, cooperation and competitiveness are investigated based on a comprehensive literature review of 210 journal papers published from 1970 to 2019 on these three topic areas, and the studies with overlapping topics. While many studied port competition, cooperation and competitiveness, very few studies exist with overlapping topic areas. From the analysis results, we find current research on the relationship of port competition and cooperation is mainly from the perspective of ports, few evaluated the implication of these strategies from different

perspectives, especially from social point of view. On the relationship of port competition and competitiveness, many considered that intra-port competition can increase port competitiveness. On the relationship between port cooperation and competitiveness, we find the cooperation among adjacent ports can improve their competitiveness when they are facing a new competitor from outside. However, both inter-port competition and cooperation are found to have positive or negative impacts, depending on the perspective of the study and the geographical location of the ports in question. The analysis of the relationships among port competition, cooperation and competitiveness is very important to the policies in port development and management, especially for China, as many coastal ports are actively following the government policy for “One Province One Port Group”.

Second, we examine the best strategies of port policy under different combinations of port attribute and shippers’ preference, considering whether there exists overcapacity or congestion, whether the ports are complements or substitutes with different degrees. A Bertrand game model is established to analyze the strategies of the ports considering the shippers’ benefit. Ports can only decide their operation strategies, whether they each decide the best prices to maximize individual profits (NC), or determine their prices jointly to maximize total profit (CO). Moreover, we include the users’ interest in integration strategy, initiated by the government, to maximize social welfare (SO). Compared the properties of three strategies, the results indicate that NC is not always the best strategy for ports, only when two port are substitutes, NC is better than CO to provide lower price, higher total throughput, consumer surplus and social welfare. In addition, CO can lead to monopoly and social welfare losses, and such losses increases with the level of overcapacity. Considering the benefit allocation between ports and shippers, government should aim at reducing congestion and avoid overcapacity, rather than encourage cooperation.

Third, we design an analytical model based on Bertrand competition to examine the decision for port using predatory pricing. Specially, we want to find what are the rules for determining the best strategy for the two ports in a duopoly market, whether predatory price is feasible, how can the dominant port drive its competitor out of the market, and whether the monopoly profit can be higher enough to offset the losses when the predatory price is used to drive the competitor out of market. The services provided by two ports are not perfect substitutes, and there exists overcapacity. The decision process includes two stages. In the first stage, the two ports compete by pricing strategy and pursue for profit maximization. While the dominating port with higher loyal customer adopts predatory price to drive the other out of market. In the second stage, after driving the competitor out of the market, the monopoly port will operate at both facilities, and determine the optimal prices at two sites to maximize total profit. Theoretical analysis is presented and numerical simulation is conducted to answer the questions. The research findings show that when Port 1(with high initial customer) drives Port 2(with low initial customer) out of the market, i.e., the market demand of Port 2 is reduced to zero, the price reduction of Port 1 is much higher than that of Port 2. However, Port 1's price can be higher or lower than that of Port 2, depends on the substitutability between the two ports. Second, when Port 1 drives Port 2 out of market, and obtains the monopoly power, the optimal price, throughput and profit in monopoly stage are larger than the Bertrand equilibriums of Port 1. Third, compared with the Bertrand equilibrium, the profit gain for Port 1 in monopoly is larger than the profit loss due to the adoption of predatory pricing strategy when the substitutability is high or there exist large overcapacity.

This thesis provides managerial insights for both port operators and public policies. From the private port business, our studies can help to better understand how competition or cooperation strategies affect port competitiveness. When considering whether to cooperate or compete, and whether to adopt predatory pricing, it is necessary to consider not only users' preference on the services provided by the involved ports, but also the current operation status of the ports. From the perspective of society, balancing the private and public interests regarding port competition and cooperation is important, and it is necessary to prevent the predatory pricing, as it can form monopoly and result in social welfare loss. With the functional development of ports, this thesis is strived to be a steppingstone for the further research on these important issues.

Keywords: Port integration; Port competition; Port cooperation; Overcapacity; Social welfare; Port policy

Publications Arising from the Thesis

Academic journal papers:

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1. Meifeng Luo, Jiantong Zhang, Fuying Chen*. (2023). "Port strategy considering port attribute and shippers' preference: analyzing port integration in China". Ready to be submitted.

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Chapter 1 Introduction

This chapter provides the research background of the thesis, the development of global maritime and port activities is introduced first, and followed by the development of port competition, cooperation and integration in China. Then the research questions and significance are raised, the structure of the thesis is presented finally.

1.1 Research background

With the rapid development of China's economy and the continuous improvement of people's living standards, transportation plays an important role in the national economy. As the most important part of international trade, the development of a country's maritime transportation directly affects its competitiveness in the international trade (Yang, Ong and Chin, 2014). According to the data from the *Chinese Ports Yearbook*, since the reform and opening-up, China's seaborne trade volume has increased from 0.44 billion tons in 1980s to 34.6 billion tons in 2020, and the proportion of the World Seaborne Trade has increased from 1.2% to 30%. Meanwhile, China's total commodity imports and exports has increased from 40 billion dollars in 1980s to 32.2 trillion dollars in 2020, accounted from 0.9% to 14.7% of the global trade, which is the highest trader in the world. The shipping industry and international trade in China promote each other and developed greatly (Wang and Zhang, 2020). As a node connecting countries and regions in the maritime trade, port has become the most important infrastructure in the development of coastal countries, and the development of hub ports or international shipping centers have become important strategies in many countries. Therefore, how to manage ports, how to promote ports, how to formulate optimal port competition strategy and promote the sustainable development of ports are critical for port operators and academics.

The Belt and Road Initiative of China clearly proposed that it is necessary to strengthen the port development of Chinese coastal cities, enhance deep regional economic cooperation with countries along Maritime Silk Road, and create a win-win community of shared interests[1]. Under this background, the port development obtained remarkable achievements. According to the data shared by World Shipping Council (Table 1-1), many ports faced lower throughput growth rates in 2020 compares with 2019, but the overall performance of Chinese ports' output remains very positive due to the early prevention and control of Covid-19 pandemic in China. There are 7 Chinese ports in the world's top 10 in terms of total container throughput for many years, including Shanghai port, Ningbo-Zhoushan port, Shenzhen port, Guangzhou port, Qingdao port, Hong Kong port and Tianjin port (Lai, 2021). In the list of the top 20 container ports, Chinese port throughputs accounted for 45% of the global total, and Shanghai Port has been in the in the first place for many years.

Table 1-1 Global top 20 container ports by total throughput in 2020

Ranking	Port	Country	Throughput (Million TEU in 2020)	Growth rate Vs.2019
1	Shanghai port	China	43.5	0.4%
2	Port of Singapore	Singapore	36.6	-1.8%
3	Ningbo-Zhoushan port	China	28.72	4.3%
4	Shenzhen port	China	26.55	3.0%
5	Guangzhou port	China	23.19	-0.2%
6	Qingdao port	China	22.01	4.5%
7	Busan port	Korea	21.59	-1.9%
8	Hong Kong port	China (Hong Kong)	20.07	8.8%
9	Tianjin port	China	18.35	5.7%
10	Port of Rotterdam	Netherlands	14.35	-3.3%
11	Dubai port	United Arab Emirates	13.5	-4.5%

[1] http://www.scio.gov.cn/31773/35507/35519/Document/1535279/1535279.htm

12	Port Kelang	Malaysia	13.24	-2.6%
13	Port of Antwerp	Belgium	12.04	-7.8%
14	Xiamen port	China	11.41	2.5%
15	Port of Tanjung Pelepas	Malaysia	9.85	7.6%
16	Kaohsiung port	China (Taiwan)	9.62	-8.3%
17	Port of Los Angeles	America	9.2	-1.1%
18	Port of Hamburg	Germany	8.7	-6.9%
19	Port of Long Beach	America	8.11	6.0%
20	Port of New York	America	7.59	2.5%

Note: Based on the top 100 container ports ranking by World Shipping Council in2020.

Moreover, with the continuous growth of international trade, global shipping industry is undergoing tremendous changes. Firstly, to pursue economies of scale, more and more shipping companies prefer to use large-scale container ships to provide scheduled service with high reliability and low cost. The largest container ship delivered at March 2023 is the MSC Tessea, which can carry a total of 24,116 TEUs[2]. Secondly, the concentration of shipping industry is very high. According to the Statistics from Alphaliner in April 2023, the top 10 container shipping companies are MSC (1st), APM-Maersk (2nd), CMA CGM (3rd), COSCO Group (4th), Hapag-Lloyd (5th), Evergreen Line (6th), ONE (7th), HMM (8th), Yang Ming (9th), Zim (10th). And the world's top 20 liner companies account for 90.6% of the world's top 100 container liner companies, as shown in Figure 1-1. Thirdly, in order to reduce operating cost, large shipping companies formed shipping alliance (M2/OCEAN Alliance/THE Alliance), which have further increased the concentration of the shipping industry. Due to the above changes, ports, especially container ports, the important nodes and hubs in maritime transportation network and logistics distribution center, have also been subjected to many changes. At present, the development of ports is faced with many opportunities and challenges. On the one hand, due to the increasing number of large container ships, many small and medium-sized ports gradually become feeder

[2] https://supplychaindigital.com/logistics/worlds-largest-container-ship-delivered-to-msc, accessed April 24, 2023

ports. Only a few hub ports with excellent natural conditions can serve ocean-going vessels. This has intensified the competition among large ports in the same hinterland to become regional hub ports (Cullinane and Khanna, 2019). On the other hand, to obtain competitive advantages, port operators invested heavily in port infrastructure and the hinterland transportation facilities. However, due to the high cost and long lead-time of port development, how ports can adapt to the changing external environment and maintain their competitiveness have become the focus of port management.

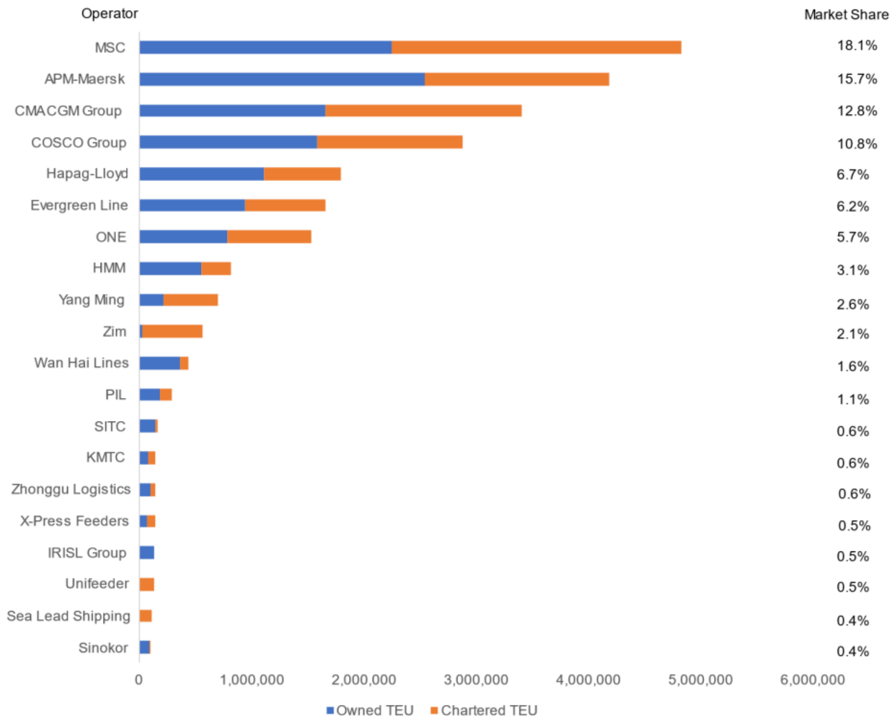


Figure 1-1 Top 20 container shipping companies by market share

Source: Alphaliner (data on April 24, 2023)

Since 2004, when the central government delegated port administrative authority to local governments, many coastal municipalities attempted to enhance port competitiveness by increasing capacity investment using scarce shoreline resources (Zheng and Negenborn, 2014). Up to now, five Multi-port groups have been successfully formed by integrating the ports in each province in Mainland China along the 18000 km coastline. On average, there is a port of over

1,000 tons for every 50km coastline (Tongzon and Dong, 2015). However, with the slowdown in the growth rate of shipping demand in the hinterland, the increasing number of ports, and the lack of relevant policies, many problems have emerged in these port clusters, including the overcapacity of ports, the waste of shoreline resources and the idle assets of terminals (Notteboom, 2010). According to statistics from the Ministry of Transport in 2014, the actual surplus in port capacity in China is on average 30%-40%, even for the ports in Yangtze River Delta region, where overcapacity is relatively small, the surplus capacity exceeds 2%, and the ports in Pearl River Delta region have about 3% surplus overcapacity (Ru and Wang, 2018). Of the 40 ports in Liaoning Province, some have nearly 50% idle assets (Guo, Yang and Yang, 2018; Dong, Zheng and Lee, 2018). In order to deal with these problems, Chinese government stipulated many policies to advocate port cooperation and integration, so as to reduce overcapacity and encourage port terminals specialization. Specifically, the pattern "One Province One Port Group" has been used to help relieve excessive competition and overcapacity (Lee and Song, 2017; Wang, Ducruet and Wei, 2015). For example, in 2008, Fangcheng port, Qinzhou port and Beihai port of Guangxi province were established through asset reorganization to unify the port infrastructure planning and provide guidance on port operation. In 2009, to enhance the regional ports competitiveness, Qingdao Port, Rizhao Port and Yantai Port signed the strategic Alliance Framework Agreement. In 2015, the Zhejiang Seaport Group was established, and now the Ningbo-zhoushan port has become the largest port in terms of total throughput in the world. At present, Ningbo-Zhoushan Port has become the world's largest port in terms of total throughput. In 2021, the annual cargo throughput of Ningbo-Zhoushan Port was 1.224 billion tons, ranking first in the world for 13 consecutive years.

It can be found that the above port policy measures mainly integrate the management mechanism and facilitate the communication of information and sharing the resource. However, it has not provided a way to reduce port overcapacity and the waste of shoreline resource still exists. Moreover, the ports that located in the same region are become more substitutable in service instead of more specialized, which intensifies competition (Lam, Ng and Fu, 2013). Some port operators indicated that they still face fierce competition with from other ports in the same region after port integration. Besides, someone pointed out that port integration may lead to regional port monopoly, which can harm the interest of consumers and reduce the social welfare (Xing, Liu and Chen, 2018). This further promotes ports to take price-cutting strategy to attract limited cargo, and intensifies the competition between ports. In order to alleviate the negative effects of port overcapacity and fierce competition, it is necessary to make a comprehensive analysis on port competition, cooperation and integration, to find out how to improve the competitiveness of ports, and to setup proper government policy to benefit both ports and shippers. Therefore, this thesis extends the studies on port competition, cooperation and integration on both theoretical and empirical aspects.

Specifically, we first analyze the evolution and relationship among port competition, cooperation and competitiveness. From the port operator's point of view, improving competitiveness is a must to attract both investors and customers, and to be successful in today's competitive environment, intra-port competition can increase the competitiveness of the port, and port cooperation can enhance the competitiveness of the port cluster, which is a preferred one for port to enhance their competitiveness when facing external competitor? These questions require a better understanding on the relationship among port competition, cooperation and competitiveness. From social point of view, having an efficient and competitive port system is very important not only for the commodity trade of that country, but also for the economic development in port cities. Therefore, to balance the private and public interests regarding port competition and cooperation, it is very important to understand the relationships among port competition, cooperation and competitiveness.

Having explored the relationships among port competition, cooperation and competitiveness, we then investigate which strategy (competition or cooperation) should a port take under different combinations of port attribute (overcapacity/congested) and shippers' preference (complement/substitute). Like many other industries, the port industry also faces many opportunities and challenges. The increasing popularity of door-to-door transportation service requires ports to form seamless connections with other transportation sectors, the large-scale ships require ports to invest more in infrastructure and become the hub ports. The overlapping of service hinterland and diversification of port investment further increased the competition among ports in the same region. Faced with such a complex environment, it is urgent for port to adopt proper strategy to maximize profits. However, from the perspective of the government, the interests of ports and shippers are equally important. The objective of a government should be to maximize social welfare, which contains the total benefit of ports and shippers. Therefore, analyze port policy and adopt proper port competition and cooperation strategies is of great significance to the interests of ports and shippers. Especially for China, as many coastal ports are actively following the government policy in "One Province One Port Group".

In addition, after analyzing the impacts of port attribute and shippers' preference on port policy, we examine how one port uses predatory pricing strategy to drive its competitor out of the market, to examine whether predatory pricing is feasible in the shipping market. Specifically, the following research questions can be arisen: How does the predatory pricing strategy come into being in port competition? In which circumstance could one port use preemptive price to drive its competitor out of the market and obtain the whole market share? When the dominant port drives its competitor out of the market, and obtain the monopoly market, can the monopoly profit be higher enough to offset the losses when it uses the predatory price to drive the competitor out of market? The answers to these questions have become the key to port operation and management, which can help to have a better understanding on the government's integration strategy and to balance the benefits and possible negative impacts of port horizontal integration in the “One Province One Port Group” policy.

1.2 Research questions

Given the background above, our research questions are three-fold.

Question of study 1:

From the port businesses’ perspective, improving competitiveness is a must to attract both investors and customers, and many studies concluded that it is better to cooperate, rather than compete, when they are facing external competitors. Then how to promote port competitiveness, which strategy (competition or cooperation) should ports use to enhance their competitiveness? More importantly, how to balance the private and public interests regarding port competition and cooperation? In short, to balance the private and public interests regarding port competition and cooperation, it is very important to understand the relationships among port competition, cooperation and competitiveness.

In study 1, we attempt to identify their relationships based on a comprehensive literature review of 210 journal papers published from 1970 to 2019 on these three topic areas, and the studies with overlapping topics. The results reveal that current research on the relationship of port competition and cooperation is mainly from the perspective of ports, few evaluated the implication of these strategies from different perspectives, especially from social point of view. On the relationship of port competition and competitiveness, many considered that intra-port competition can increase port competitiveness. However, both inter-port competition and cooperation are found to have positive or negative impacts, depending on the perspective of the study and the geographical location of the ports in question. Through this review, we hope to motivate further research on the benefits of competition and cooperation strategies from different perspectives and different governance levels.

Question of study 2:

Chinese government initiated the port integration policy to encourage cooperation among the ports in the same region. Then, what are the impacts of different strategies (competition/cooperation) from the perspective of port businesses, shippers and the society? Is government integration really necessary? How much difference it can make compared with no policy, i.e., allow port operators to decide their best strategies?

To solve this problem, in study 2, we analyzed whether two ports should cooperate and whether the port integration policy is necessary, considering both port attribute (overcapacity/ congested) and shippers' preference (complement/substitute). An analytical model is established and a numerical simulation is conducted to examine the impacts of these conditions on ports, shippers and the society. The results show that Ports naturally prefer cooperation as it can generate higher profit. For complementary ports, cooperation can also generate higher social welfare. For substitutable ports, competition is better and should be promoted, while cooperation can lead to monopoly and social welfare losses. Such losses increase with the level of overcapacity compared with competition. Hence cooperation should be prevented among substituting ports. This study could benefit the policy for regional port management, as there are always ports with different operational status and shippers' preference in a region.

Question of study 3:

The inefficiency of port resource utilization and the increasing fierce competition among ports can intensify the hub ports to use a very low price to attract the limited cargo flows. Then under what market circumstance would the port adopt predatory pricing? In economic theory, the purpose of predatory pricing in duopoly competition is to obtain the monopoly market in the future. Then how can one port decide the effective price to drive its competitor out of market considering both duopoly and monopoly stage? When the dominant port drives its competitor out of the market, and gain monopoly power, can the monopoly profit be higher than the duopoly optimal profit?

In study 3, we construct a two-stage noncooperative game model to analyze how can one port drive its competitor out of the market by predatory pricing. A duopoly market structure is taken as an example, assuming that two ports with different competitive advantages serve the same hinterland. The services are non-perfect substitutes, and ports are in overcapacity. In the first stage, the two ports compete in a duopoly market, and maximize their own profit, while the dominating port applies predatory price and tries to drive the other port out of the market. In the second stage, the monopoly port operates at both facilities, and determines the optimal prices at two sites to maximize total profits. A theoretical analysis is established and a numerical simulation is conducted to show the model results. The results reveal that price competition is feasible in some cases, especially when there is high degree of overcapacity or high substitutability between the two ports. For ports with high loyalty customers, the best strategy is to increase their competitiveness to minimize the profit loss in the process of driving its competitor out of market. This study provides useful suggestions and references for port market transformation and public policy making in the future.

1.3 Research significances

The contributions of each study are summarized in detailed in Chapter 5. In this section we briefly summarize the critical significances of this thesis for academic research and practice as follows.

Study 1 identifies the relationships among port competition, cooperation and competitiveness by reviewing 210 journal papers on these three topic areas, and the studies with overlapping topics. Through this study, it is aspired to provide a better understanding on how ports can improve their competitiveness in an increasingly interconnected market and how competitive or cooperative strategies can affect port competitiveness. It is also hoped that the benefits of competitive and cooperative strategies can be further studied from different perspectives and at different levels of governance. Moreover, this study is significant for balancing the benefits and possible negative impacts of port horizontal integration in the "one Province one port group" policy, which is also strived to be a steppingstone for the further research on these important issues.

Study 2 investigates whether two ports should cooperate and whether the port integration is necessary, considering port attribute and shippers' preference. This is the first study that compares the NC and CO under different combinations of port attribute and shippers' preference, from the perspective of ports, shippers as well as society. It can be useful for both government policies and port operators in port management. From the perspective of government, the interests of ports and shippers are equally important, the objective of government policies regarding port competition or cooperation should not only consider the users' preference on the services provided by the involved ports, but also the current operation status of the ports. While for the private port business, cooperation is always preferred as it always generates maximum total profit. However, cooperation can lead to monopoly and social welfare losses when the two ports are substitutes. Therefore, our study can provide useful suggestions for government to balance the benefits to the shippers and port operators, since any changes in these directions would upset the balance between the two sides, and result in the fluctuation in port-shipping market.

Study 3 analyzes how can one port decide the effective predatory price to drive its competitor out of the market considering the profits from both duopoly and monopoly stages. This study is important for both public policies and private port operators in port management. For government policies, it is necessary to prevent the predatory pricing, as it can form monopoly and result in social welfare loss. For private port operators, when consider adopting predatory pricing, it is necessary to consider the substitutability of the two ports and supply-demand relationship of the port services in the region. Study 3 provides useful insight into the formation of public polices when ports business faced with market transition and evolution.

1.4 Structure of the thesis

This thesis consists of five chapters, and the structure of this thesis work is organized as follows:

Chapter 1 introduces the research background of this thesis. The development of global maritime and port activities is introduced first, followed by the development of port competition, cooperation and integration in China. Then, the research questions, significance and together with the structure of the thesis are provided.

Chapter 2 analyzes current studies on port competition, cooperation and competitiveness and identify the relationships among the three topics. First, the existing research articles on the three topic areas are collected, and the studies with overlapping topics are identified, followed by classification and distribution according to the region of the research and topic area. Second, the existing studies on port competition, cooperation and competitiveness are summarized respectively, and the literature with overlapping topic areas are presented. Third, the relationship among the three topics are discussed, and conclusion are proposed finally.

Chapter 3 investigates port policy considering both port attribute and shippers' preference: analyzing port integration in China. It is a theoretical analysis based on the findings in Chapter 2. We build a game model to formulate the equilibrium results (including price, total quantity, total profit, consumer surplus and social welfare) of CO, NC and SO, then compare the equilibrium results among three cases under different combination of port attribute and shippers' preference, followed by some propositions and numerical simulation analysis. The last two sections discuss policy implications and summarizes the major findings in this research.

Chapter 4 examines the feasibility of predatory pricing in port competition. A two-stage game model is constructed to analyze how can one port drive its competitor out of the market. In the first stage, two ports compete with differentiated service advantages, each port chooses their optimal price to maximize its own profit. While the port with higher loyal customer service attempts to use predatory pricing to drive the other one out of the market. In the second stage, the port which obtained the monopoly power will decide the optimal prices to maximize the profit in both regions. A theoretical analysis is conducted and a numerical simulation is proposed, discussion and conclusions are presented finally.

Chapter 5 summarizes the conclusions in this thesis. It also includes the research limitations and future research directions. The structure of this thesis is shown in Figure 1-2.

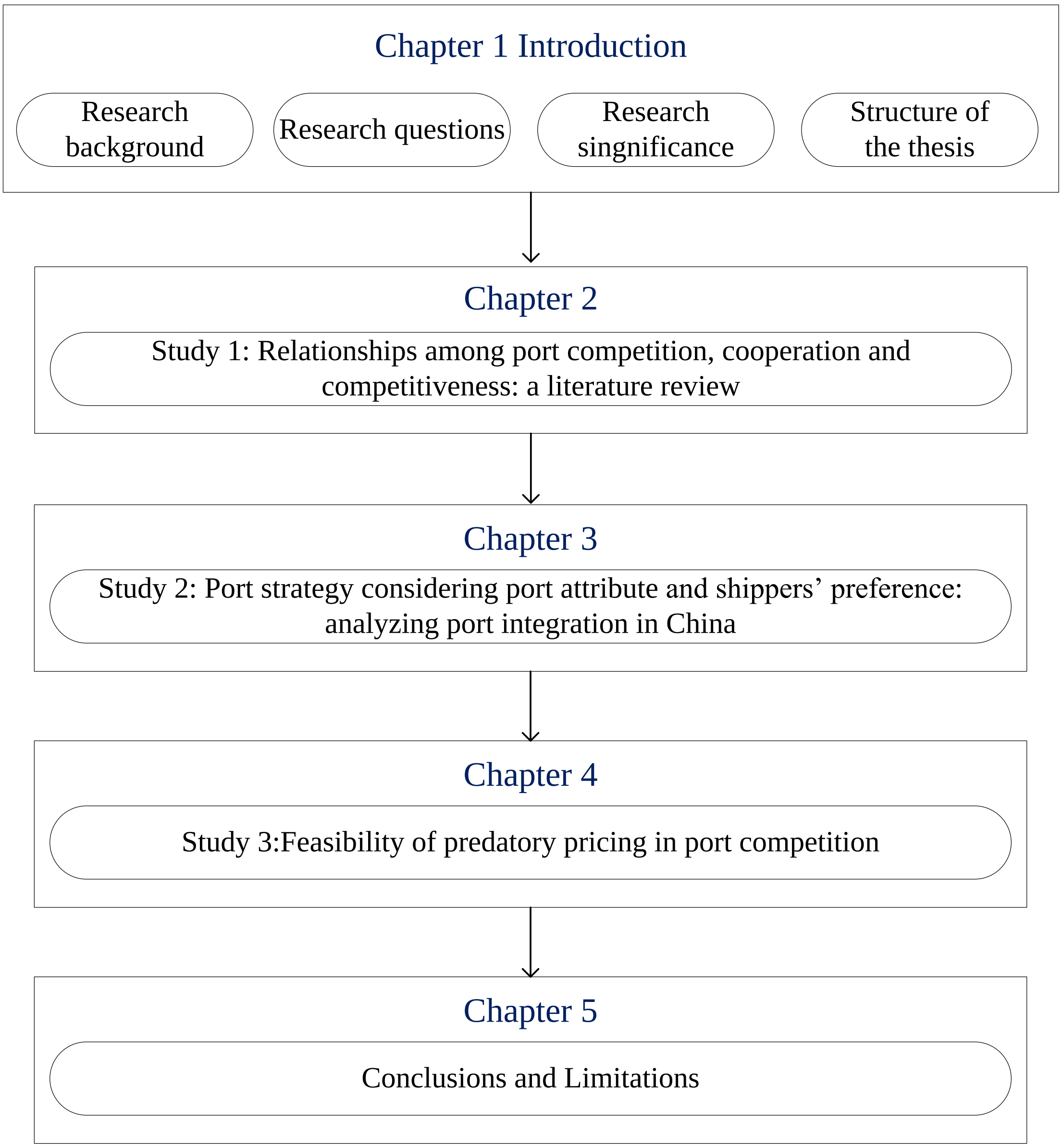


Figure 1-2 The structure of the thesis

Chapter 2 Relationships among port competition, cooperation and competitiveness: a literature review

This chapter attempts to identify the relationships among port competition, cooperation and competitiveness, which is critical for both port operations and public interests. Although the number of studies on these three topic areas increased significantly in the recent decades, the relationships among them have not been sufficiently clarified. This study attempts to identify their relationships based on a comprehensive literature review of 210 journal papers published from 1970 to 2019 on these three topic areas, and the studies with overlapping topics. While many studied port competition, cooperation and competitiveness, very few studies exist with overlapping topic areas. Current research on the relationship of port competition and cooperation is mainly from the perspective of ports, few evaluated the implication of these strategies from different perspectives, especially from social point of view. On the relationship of port competition and competitiveness, many considered that intra-port competition can increase port competitiveness. However, both inter-port competition and cooperation are found to have positive or negative impacts, depending on the perspective of the study and the geographical location of the ports in question.

2.1 Introduction

Competition and cooperation are two of the most important decisions of a port in dealing with its neighboring ports. With the rapid development of international trade and further specialization in port and shipping starting from 1960s, port productivity and efficiency have been greatly improved (Garnett, 1970). More ports are being built in the close vicinity and better transportation facilities enable each port to access a larger hinterland. As a result, seaports no longer have exclusive hinterland and competition exist among the ports servicing the customers in the same area. They have to promote their respective competitiveness in order to out-perform the others in the competition and survive in the market (Cullinane et al., 2004; Chang and Talley, 2019). However, cutting-throat competitions can reduce the profitability of a port, which encourages more cooperation in different aspects, such as joint operation or infrastructure development, or even merge (Song, 2003). Then, how to promote port competitiveness, and which strategy to adopt (competition or cooperation)? These are critical questions for both the performance of the port, and the public policies regarding port development and operation. Therefore, understanding the relationships among port competition, cooperation and competitiveness can benefits both port businesses and public policies.

From the businesses' point of view, improving competitiveness is a must to attract both investors and customers, and to be successful in today's competitive environment. It is well-known that intra-port competition—the internal competition among the terminal operators in a port—can improve the competitiveness of the port. However, many studies found that ports are better to cooperate when facing new competitors from outside, because it can increase their collective competitiveness (Hoshino, 2010; Hwang and Chiang, 2010; Zhou, 2015). Why internal competition among terminal operators in a port can increase the competitiveness of a port, but not the competition among ports in a port cluster when it faces external competitor? Which strategy should ports use to enhance their competitiveness when facing external competitor? As competition can drive down profit margin and cooperation may result in inefficiency, both are critical for business operation. Then, which strategy to adopt is critical for business performance, which requires a better understanding on the relationship among these three aspects.

From social point of view, having an efficient and competitive port system is very important not only for the commodity trade of that country, but also for the economic development in port cities. Competition is usually preferred from social perspective, as it can reduce user cost and increase social welfare. However, if competition results in low profit margin, it is detrimental to the continuous investment in the port capacity, which can result in inefficiency. On the other side, port cooperation or integration, although preferred by the port business as it can increase market power, may also result in inefficiency. Therefore, to balance the private and public interests regarding port competition and cooperation, it is very important to understand the relationships among port competition, cooperation and competitiveness.

There are many existing studies about port competition, cooperation and competitiveness. However, most of the papers have their own specific topic area, due to the nature of academic research. For example, Song (2003) studied port co-opetition that combines competition and cooperation for inter-port relationship; Zhou (2015) analyzed the best strategy (competition or cooperation) when facing new competitors; De Langen and Pallis (2006) and De Oliveira and Cariou (2015) investigated the impact of competition on port competitiveness; Tian, Liu and Wang (2015) identified the change of competition relationship overtime; Cullinane, Teng and Wang (2005) evaluated port competitive position; Hwang and Chiang (2010) found cooperation and co-opetition can enhance the competitiveness of port cluster, and Song and Panayides (2008) analyzed the impact of port integration in the supply chain on port competitiveness. However, no studies have summarized the relationships among these three topic areas based on the existing literature.

This paper aims to fill in the gap by analyzing the relationships among port competition, cooperation and competitiveness based on a review of existing literature on these topic areas and identifying the studies with overlapping topic areas. Through this review, it is aspired to provide a better understanding on how port can improve its competitiveness in the increasingly interrelated market, and how competition or cooperation strategies can affect port competitiveness. It also hopes to motivate further research on the benefits of competition and cooperation strategies from different perspectives and different governance levels.

The remainder of the paper is constructed as follows. Section 2.2.2 presents the data collection procedure, classification and research distribution. To provide a basis for the relationship of three topic areas, Section 2.2.3 summarizes the existing studies on port competition, cooperation and competitiveness. Section 2.2.4 presents the literature with overlapping topic areas. We further discuss the relationship among the three topics in Section 2.2.5, and summary and conclusions are provided in Section 2. 6.

2.2 Data collection and research classification

This section presents the process of data collection and classification, together with the distribution of the existing research across time, journals and topic areas. The existing research articles are collected using Google Scholar search in the paper title, abstract and keywords. As the relationships among these topic areas have to be from the literature in each of the topic area, we first collected the existing journal publications in all these three areas using the following keywords: "port competition", "port cooperation", "port co-opetition", "port alliance", "port integration", "port competitiveness", "port choice", "port efficiency", and "port performance". A total of 256 publications are collected initially. After reading each paper carefully, we removed book chapters, conference papers and dissertations, and those not really study port competition, cooperation and competitiveness. For example, many studies on port efficiency or performance do not take "port competitiveness" as the objective, they only evaluated port efficiency or performance. The remaining 210 articles are from peer-reviewed journals in English language, which are published from 1970 to 2019. Table 2-1 presents the distribution of these 210 papers according to the publishing journals, together with their percentage shares.

Table 2-1 The major journals of the selected papers

Academic journals	No. papers (1970-2019)	%
Maritime Policy & Management	40	19.05
Maritime Economics & Logistics	14	6.67
The Asian Journal of Shipping and Logistics	13	6.19
Research in Transportation Business & Management	13	6.19
Transportation Research Part A	11	5.24
Transportation Research Part E	11	5.24
Transport Reviews	7	3.33
Journal of Transport Geography	7	3.33
International Journal of Shipping and Transport Logistics	4	1.90
Transport Policy	4	1.90
Transportation	4	1. 90
Transportation Research Part B	4	1. 90
Journal of Marine Science and Technology	3	1.43
Journal of Transport Economics and Policy	3	1.43
International Journal of e -Navigation and Maritime Economy	3	1.43
Transportation Research Record	2	0.95
Economic Geography	2	0.95
European Journal of Operational Research	2	0.95
European Transport	2	0.95
Journal of Navigation and Port Research	2	0.95
Journal of the Eastern Asia Society for Transportation Studies	2	0.95
International Journal of Logistics Research and Applications	2	0.95
International Journal of Transport Economics	2	0.95
Asia Pacific Viewpoint	2	0.95
Other journals (one article each)	51	24.29
Total	210	100

From Table 2-1, more than 25% of the papers are published in two core maritime journals: *Maritime Policy & Management* (40), *Maritime Economics & Logistics* (14). This indicates the importance of these two journals in this area. The next two journals are *The Asian Journal of*

Shipping and Logistics (13) *and Research in Transportation Business & Management* (13), which accounted for 12% of all the papers in this area. Also, many papers are published in transportation journals, reflecting the academic hierarchy of transportation and maritime studies.

Figure 2-1 shows the distribution of selected papers from 1970 according to the region of the research (a) and topic area (b). Overall, the number of publications is quite small before 2003. This indicates that the port competition or cooperation is not a very big issue until the 2003, two years after China joined the World Trade Organization. The fast increase in the international trade brought a surge in port development worldwide, which in turn motivated the needs in the academic research in this area.

In terms of geographical distribution, the earliest studies are from America, which include North and South America. After 2003, the number of studies on Asia ports experienced the highest increase, followed by that on European ports. Also, a large number of studies have no specific port regions, which are put under "general" group.

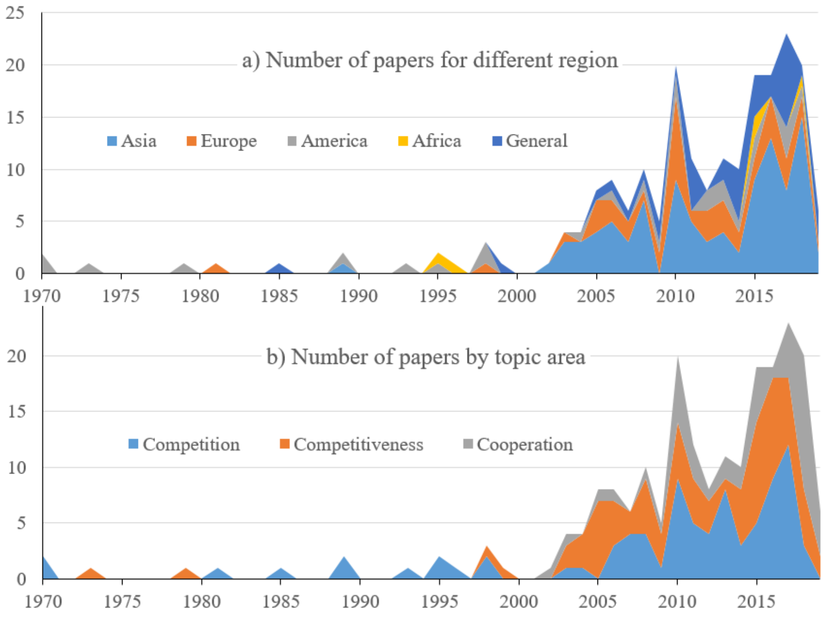


Figure 2-1 Distribution of selected papers from 1970

Panel (b) in Figure 2-1 summarizes the evolution on the number of papers in three topic areas. It shows that the studies on these three areas do not appear at the same time. Research on port competition appeared first in 1970, then came port competitiveness in 1973, and port cooperation in 2003. Also, most of the papers are on port competition and competitiveness, very few of them are on port cooperation.

Finally, to study the relationship among these three topic areas, the papers on each topic and those with overlapping topic areas are identified after reading the full paper. Thus, the collected papers are classified into six categories, i.e., in addition to the original three topic areas (competition, cooperation and competitiveness), we added three overlapping groups (cooperation & competition, cooperation & competitiveness, and competition & competitiveness). The distribution on the number of papers in each group is summarized in Figure 2-2.

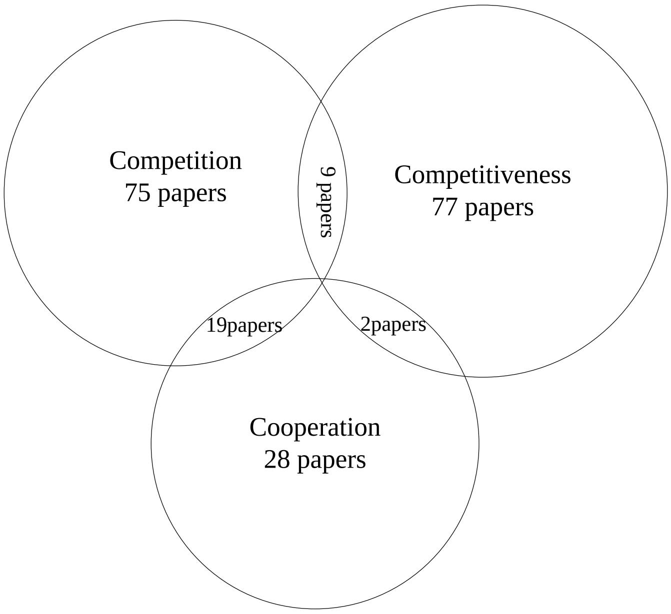


Figure 2-2 Classification of the research topics with overlapping topic areas

Compared with the number of papers with single research topic (75+77+28=180), there are only 30 papers with overlapping topic areas. This indicates the needs for the study in the relationships among port competition, cooperation and competitiveness. Next, we first summarize research on port competition, cooperation and competitiveness in Section 2.3, and those with overlapping topic areas in Section 2.4.

2.3 Research on port competition, cooperation and competitiveness

To understand the relationships among port competition, cooperation and competitiveness, it is important to first examine the research in these three areas. Therefore, we first review the existing studies in each topic area.

2.3.1 Research on port competition

The study on port competition has the longest history as it enjoys the central position in port development, operation and management. Whenever ports provide similar services for the overlapping hinterland, competition naturally exists (Slack, 1985). With more new ports being built to cater for the increasing demand, or the development of transportation facilities enables a port to serve a broader region, the level of competition also increases (Verhoeff, 1981). This has drawn the attention of scholars with different perspectives and objectives since 1970s. There are 75 papers in port competition. After reading the full paper, they can be categorized into three groups (Table 2-2), based on whether the competition is internal or external to a port, what affects port competition, and what are affected. The first is on port competition strategies, the second is about the impacts of external policies on port competition, and the third is the evolution of port competition and its impact.

Table 2-2 Research topics and methods on port competition

Research topics	Research methods
1. Port competition strategies (41)	
Inter-port competition strategies (37) Intra-port competition strategies (4)	Game-theoretical model (14); Regression analysis (4); Questionnaire (2); Case study (2); Literature review (2); Stochastic model (2); Comparative study (1); Error correction model (2); Structural equation model (1); Logit model (1); Markov chain model (1); Network analysis (1); Others (8)
2. Impacts of external policies on port competition (25)	
Port investment (6) Capacity expansion (2) Port privatization (3) Road congestion (2) Others (12)	Game-theoretical model (10); Case study (2); Optimization model (2); Comparative study (1); Life cycle analysis (1); Network analysis (1); Stochastic model (1); Others (7)
3. The evolution of port competition and its impact (9)	
The evolution of port competition (5) Port competition impacts on governance (4)	Game-theoretical model (2); Qualitative analysis (2); Network analysis (1); Optimization model (1); Error correction model (1); Others (2)

Note: number of papers in the parenthesis.

2.3.1.1 Studies on port competition strategies

Due to the *ex-anti* nature of port competition strategy, one of the main topics in port competition is to analyze port competition strategies under different environments. Port operators could consider a variety of options in practice, including inter-port or intra-port competitions (Song et al., 2016). In this direction, game-theoretical model is the most common method to analyze strategic behavior among competing ports.

As listed in Table 2-2, many papers investigated inter-port competition strategy by game-theoretical model. For example, Luo, Liu and Gao (2012) built a two-stage game model to analyze the competition between Hong Kong port and Shenzhen port that both serve the PRD region, including a pricing subgame model in the first stage and a capacity expansion game model in the second stage. The results explained the transition of container port market in the past and predicated the possible results of the competition between these two ports. Ishii et al. (2013) constructed a non-cooperative game-theoretical model to investigate port competition with the strategy of selecting port charges under uncertainty, and they deduced the Nash equilibrium and obtained some propositions with the case of Busan port and Kobe port. For intra-port competition, Kaselimi, Notteboom and De Borger (2011) analyzed the competition among multi-user terminals by game-theoretical approach with the horizontal differentiated service, and the results demonstrated that the shift toward a fully dedicated terminal affects intra-port and inter-port competition among the remaining multiuser terminals. Yip et al. (2014) developed a game model where two terminal operators applied for franchise rights in two adjacent seaports, and found that if both terminal operators expanded, they would become worse with the increase of inter-port competition and intra-port competition.

Intra- and inter-port competitions are the competitions at different levels. With the increase in the demand for shipping, more ports are being built, port competition is extending from local, to regional and national and even international level. The involvement of public interest in the port development and operation is inevitable for the competition at national level. Then, how to balance different interests and maintain a level playing field in such competition may become a hot topic.

2.3.1.2 Impacts of external policies on port competition

In addition to the research on port competition strategies, many also studied how the external policies, such as related with port investment, privatization, environmental issues, etc., affect port competition. Verhoeff (1981) pointed out that in European Community (EC), the involvement of public authorities in port services could result in a price war among the ports in different countries. It alters the natural advantages of the competing ports, and can result in welfare losses. Van Hassel et al. (2013) examined the impacts of different environmental policies, namely the internalization of external cost of European hinterland transportation and the Sulphur Emission Control Area in the North Sea, on the competition between ports in the Hamburg-Le Havre range and those in Southern Europe. Their impacts are found to be insignificant. Wilmsmeier and Sanchez (2017) applied the life cycle analysis to study how the institutional structure and port governance are evolved, and how they affect the port competition in Chile.

Policies regarding port investment and privatization are critical external factors in port competition, Kent and Hochstein (1998) reviewed the competitive environment of Colombia and suggested the privatization and reform plan for ports with limited cargo volumes. Czerny, Höffler and Mun (2014) investigated the impacts of port privatization on social welfare, where the two ports located in different countries handling their own cargos and transshipment cargos. The results provided additional support on the benefits of port privatization. Cheng and Yang (2017) studied port investment equilibrium when the competing ports have different objectives: maximizing port profit or maximizing local GDP. They found that maximizing GDP would result in much larger investment compared with maximizing profit.

From these studies, the environmental policies that have overall regional impacts on the transportation activities might not change the competition relationship of the ports in the region. However, public involvement and privatization policies would have significant impacts. Therefore, for ports at different competitive environment, it is challenging to consider the appropriate policy to balance the public and private interests.

2.3.1.3 The evolution of port competition and its impact

After 1980s, the evolution of port competition first obtained attentions from academics in Europe and United States. Fleming (1989) analyzed the evolution and development of US West-Coast ports, and discussed the problems of competition between container ports. With the increase of global trade and economic development, the range of port competition has expanded to the whole East Asia region (Yap, Lam and Notteboom, 2006; Huang, Chang and Wu, 2008). Yap and Lam (2006) used error correction model to analyze the inter-port competitive dynamics among the major container ports in East Asia. They found that the competition among East Asia ports increased as the cargo hubs shifted to mainland China. Tian, Liu and Wang (2015) developed an econometric model to estimate the demand growth of container shipping and measured the competitive relationship of ports. They found that Shenzhen port is a substitute on the transshipment container of Hong Kong port. But for direct cargo, they are complements. Generally, the level of competition is increasing and its impact has extended from nearby ports to among the distant ports.

Port competition also has impacts on port performance and government policies. For example, Yuen, Zhang and Cheung (2013) investigated how foreign and local ownerships affect China's container terminal efficiency based on DEA analysis. They found the Chinese government should encourage both foreign investment and local participation in transportation infrastructure development for improving port performance. Knatz (2017) examined how competition affect governance and strategic decision-making at U.S. seaports, and found that the traditional business model in landlord port was no longer viable in large container ports. These shows the port competition on port governance should be adaptable based on the port development stage at different country. For the former (Yuen, Zhang and Cheung, 2013), the foreign investment can help to bring the port operation up to the global frontier, while the later (Knatz, 2017) suggests more cooperation among the ports and terminal operators to avoid over-investment in port capacity expansion.

2.3.2 Research on port cooperation

Generally, when two entities can produce a higher return together than on their own, there is a ground for cooperation. Therefore, port cooperation can take many different forms, and its research can cover a very broad topic area. Ports handling different types of cargos can cooperate to achieve better management of access channels, and those in the same import/export chain can cooperate to better serve their customers. In the existing literature, there are 28 papers in this topic area. After reading the full paper, these papers are found to mainly focus on two directions: development and impact of port cooperation, and port integration (Table 2-3). The former is mainly on the development of port cooperation and its impact. The latter is a specific form of port cooperation at local level.

Table 2-3 Research topics and methods on port cooperation

Research topics	Research methods
1. Development of port cooperation and its impact (12)	
Development of port cooperation (6)	Qualitative analysis (2); Game-theoretical model (1);
Impact of port cooperation (3)	Case study (1); Grey relational degree analysis (1);
Others (3)	Factor analysis (1); Cluster analysis (1); Others (5)
2. On port integration (16)	
Horizontal integration among ports (8)	Game-theoretical model (3); Case study (2);
Vertical integration in supply chain (8)	Hierarchical regression analysis (2); Bi-objective programming (1); Optimization model (1); Comparative study (1); Others (6)

Note: number of papers in the parenthesis.

2.3.2.1 Development of port cooperation and its impact

Facing an increasing competitive pressure, many ports have considered cooperation. Ryoo (2011) investigated the motivations and types of port cooperation, and pointed out that port cooperation can be formal or informal, and horizontal or vertical. Port integration between port related organizations and various maritime players is an specific type of port cooperation. Stamatović, de Langen and Groznik (2018) developed a cooperation matrix to study the scope and depth of cooperation in the North Adriatic ports, and found that their current level of cooperation is limited to non-commercial lobbying and joint marketing activities. Huo, Zhang and Chen (2018) analyzed port cooperation strategies in China. They concluded that the domestic port cooperation would result in provincial port groups, and international port cooperation is motivated by the Belt and Road Initiative.

There are also several studies investigating the impact of port cooperation. Li and Jiang (2014) used the grey relational degree model to evaluate the performance of cooperation between seaport and dry port. They found that the cooperation between Qingdao seaport and Xi'an dry port has resulted in deficiencies in customer satisfaction, financial cooperation and non-market tools. Donselaar and Kolkman (2010) studied the impact of cooperation between port authorities on social welfare. It concluded that such cooperation can offset the negative impacts of port competition for cargo and improve the competitive position over the ports in other nations. Of course, the cooperation related two seaports and port cooperation between sea and dry port are different, and we will distinguish them in Chapter 3.

2.3.2.2 Studies on port integration

With the economy slows down and competition intensifies, port integration is gaining importance, and many scholars have investigated port integration and alliance. For horizontal integration among terminals or ports, Saeed and Larsen (2010) applied a two-stage game to examine the integration strategy among three container terminals that located in Karachi Port in Pakistan, and found that the integration could result in a higher price. This is expected as horizontal cooperation can increase the market power. However, opposite results are obtained in Dong, Zheng and Lee (2018) due to their assumption that integration can reduce the marginal cost of both ports in the model. For the vertical integration of ports in the supply chain, Song and Panayides (2008) measured port/terminal integration in the supply chain and its impacts on port competitiveness. Theo E. Notteboom et al. (2017) examined how the involvement of shipping lines in container terminals affects port selection in inter-continental liner service network. They found that ports would have a much higher chance of receiving calls of an alliance when the members were stakeholders of the port terminals. This is consistent with general belief that vertical integration can increase the competitiveness of the port.

2.3.3 Research on port competitiveness

Port competitiveness is defined as "the degree to which a port competes with another port or ports" (Chang and Talley, 2019), which is another important research direction in port studies, as determines whether a port can out-perform its competitors. In the review process, after reading the full paper, it is found that many take port performance or efficiency the same as port competitiveness. However, the former may be only interested in evaluating port performance or efficiency. Those papers that do not take "port competitiveness" as the objective in their studies are excluded. As a result, a total of 77 papers are collected in this area (Table 2-4). Most of the studies are focused on three directions: what makes a port competitive, how to evaluate, and how policies can affect it. Therefore, we categorized this topic area into three main topics: identifying the key factors for port competitiveness; evaluating competitiveness among ports; and analyzing the policy impact on port competitiveness and efficiency.

Table 2-4 Research topics and methods on port competitiveness

Research topics	Research methods
1. Key factors in port competitiveness (31)	
Determinates in port competitiveness and selection (26) Determinates in port performance and efficiency (2) Others (3)	Review (5); Analytic hierarchy process (4); Factor analysis (3); Qualitative analysis (3); Questionnaire (3); Network analysis (2); Choice model (2); Stochastic frontier model (2); Logit regression (1); Benchmarking (1); Structural equation modelling (1); Fuzzy structuring model (1); Comparative study (1); Principle component analysis (1); Others (1)
2. Evaluation of port competitiveness (22)	
Evaluation of port competitiveness (22)	Analytic hierarchy process (8); Comparative study (2); Entropy TOPSIS (2); Simulation (2); Cluster analysis (1); Factor analysis (1); SWOT analysis (1); Grey relation analysis (1); Multi-criteria evaluation model (1); Questionnaire (1); Benchmarking (1); Quantity-setting model (1)
3. Policies affecting port competitiveness (24)	
Impact on competitiveness (21) Impact on efficiency (3)	Data envelopment analysis (2); Simulation (3); Factor analysis (2); Hierarchical fuzzy analysis (1); Survey (2); Multi-criteria ranking (1); Questionnaire (1); Network analysis (1); Optimization model (1); Structural equation modeling (1); Hypothesis testing (1); Others (8)

Note: number of papers in the parenthesis.

2.3.3.1 Key factors in port competitiveness

Many have investigated what affects port competitiveness, including identifying the factors for port competitiveness and port selection, port performance and efficiency.

On the factors for port competitiveness, Sun and Bunamo (1973) examined port competitiveness through investigating competition for foreign trade cargos, and they found that the trading partner, the geographical concentration of production and commodity composition are three key factors of U.S. port competitiveness. Song and Yeo (2004) found the geographical location was very important for the competitiveness in Chinese container ports. da Cruz, Ferreira and Azevedo (2013) pointed out that the ocean carriers and terminal operators have different views on important factors for port competitiveness. Carriers consider vessel turnaround time to be the key factor, while terminal operator thought seaport facilities and equipment as the most important factor. Guy and Urli (2006) considered port infrastructures, total transit cost and geographical location, and fourteen sub-criteria in studying port selection behavior. Parola et al. (2017) reviewed existing studies and found that economies of scale in shipping, governance changes, coopetition with nearby ports, the rise of port networks, green and sustainability challenges are five main drivers that moderate the impacts of traditional factors and reshuffle their relative salience on port competitiveness. In addition, some have studied major factors for port performance and efficiency as they are also the indicators for port competitiveness. Tongzon and Heng (2005) found that private sector participation in the port industry can improve port operation efficiency, and further improve port competitiveness. Thai and Grewal (2005) pointed out that the handling productivity, the reform of administrative procedures, hinterland connection, coordination of activities and human resource development are important in improving the efficiency and competitiveness of Vietnamese port system.

As ports are operating in a complicated environment, it is expected that many factors can be identified as important for improving its competitiveness. Also, they are likely to be different if considering specific definition of competitiveness, such as from different perspective (carriers or terminal operators) or for different cargoes.

2.3.3.2 Evaluation of port competitiveness

Competitiveness is an abstract and intangible term. Therefore, the evaluation of port competitiveness may consider many different evaluation methods, also can include both observable data and subjective rating. For example, Song and Yeo (2004) used Analytic hierarchy process method (AHP) to evaluate the competitiveness of container ports in China, and found Hong Kong port to be the most competitive, followed by Shanghai, Yantian, Qingdao, Shekou, Dalian, Tianjin, and Xiamen. Dyck and Ismael (2015) evaluated the competitiveness of major West African ports using AHP. Huang et al. (2003) used Fuzzy Multi-criteria Grade Classification model to evaluate East Asia container ports (Singapore, Kobe, Pusan, Hong Kong, Shanghai, Kaohsiung, Taichung, and Keelung) based on 31 indicators. These analyses, although subjective, can be very useful for the port planner to identify the area of improvement by comparing the criteria across different ports. In addition to AHP, TOPSIS (Technique for Order Preference by Similarity to an Ideal Solution) is another popular method in port competitiveness evaluation. Kim (2016) investigated the main factor for port competitiveness for selected ports in Korea and China using Entropy-TOPSIS, and the results indicated that Shanghai, Shenzhen and Busan port are the top three competitive ports. Kim and Lu (2016) compared the competitiveness of Busan port and Shanghai port using entropy weigh TOPSIS, and found Shanghai port is more competitive in port throughput criteria than Busan port, and Busan port is more competitive in port facilities criteria than Shanghai port. Other methods are also used to analyze port competitiveness, Ng et al. (2010) used Data Envelopment Analysis (DEA) and survey method to assess port competitiveness for regional container hub ports, and found that Shanghai and Tanjung Pelepas are the future potential hubs.

2.3.3.3 Policy impacts on port competitiveness

For the policies impact on port competitiveness and efficiency, Tongzon and Heng (2005) applied SFA model to examine the technique efficiency in container ports, and they found that private sector's participation in port industry can improve port operation efficiency and enhance port competitiveness. Ng and Gujar (2009) used empirical analysis to investigate how Indian government policies could shape an industry's competitive structure, especially increase the dry port's efficiency and competitiveness. Moon and Woo (2014) constructed a simulation model based on system dynamics to investigate how port operation affect the efficiency of ship operation in liner shipping from both economic and environmental perspectives, and the results showed that less time in port can improve efficient ship operation in terms of operating cost. Jeevan, Chen and Cahoon (2018) used exploratory factor analysis to examine the impact of dry port operations on seaport competitiveness, and the results showed that dry port operations can enhance seaport performance and improve trade volume.

2.4 Research with overlapping topic areas

To identify the relationship among the research in port competition, cooperation and competitiveness, we first identify the selected papers that have overlapping topic areas. As showed in Figure 2-2, there are only 30 papers with overlapping topic areas (19 in competition & cooperation, 9 in competition & competitiveness, and 2 in cooperation & competitiveness). Although relatively small in number of publications, they provided a direction for us to explore the relationship among these three.

There are 19 papers studying both port competition and cooperation. Such studies include identifying or describing the competition-cooperation relations among the ports in a region (Ma and Qian, 2011; Song, 2002; McLaughlin and Fearon, 2013; Castelein, Geerlings and Van Duin, 2019). Many have studied the best strategy for ports (cooperate or compete) when facing other competitors (Li and Oh, 2010; Hoshino, 2010; Wang et al., 2012; Zhou, 2015; Xing, Liu and Chen, 2018; Shinohara and Saika, 2018; Xiao and Liu, 2017), or facing increasing trade volume and containership sizes (Trujillo, Campos and Pérez, 2018). There are also studies about the impacts of port cooperation/competition strategies on port investment (Wang and Zhang, 2018), on environmental policy (Cui and Notteboom, 2017) and on hub-port selection (Asgari, Farahani and Goh, 2013), as well as the impact of vertical cooperation between port and inland transportation service provider on port competition (Óscar Álvarez-SanJaime et al., 2015). Also, some proposed port co-opetition (Song, 2003; Kramberger et al., 2018; Kavirathna, Kawasaki and Hanaoka, 2019), which is the strategy for ports to cooperate and compete at the same time.

The 9 papers in port competition and competitiveness are mainly concerned the impacts of port competition on competitiveness or efficiency (Yuen, Zhang and Cheung, 2013; Coto-Millán et al., 2016), including both intra-port competition and inter-port competition (De Langen and Pallis, 2006; De Oliveira and Cariou, 2015). Some have examined the major factors on regional port competition and provided strategies for improving competitiveness (Musso, Piccioni and Van de Voorde, 2013), or analyzing the evolution of competition relationship and relative competitiveness (Tian, Liu and Wang, 2015). Some analyzed the impacts of the restructuring of liner shipping service on port selection and competition (Rimmer, 1998). There are also some who ranked port competitiveness over a large number of ports (Huang et al., 2003; Song and Yeo, 2004), which can help the ports that are in competitive relationship.

Only 2 papers are in port cooperation and port competitiveness. One found that cooperation and co-opetition between adjacent ports would enhance port competitiveness in the same region (Hwang and Chiang, 2010), another examined the impacts of vertical integration of ports or terminals in the supply chain on port competitiveness (Song and Panayides, 2008).

Also, there are 6 papers that are classified into port competition group from the Google

Scholar search are better to be grouped in port competitiveness. Most of them are on port competition for specific types of cargoes, such as Sun and Bunamo (1973) and Ffrench (1979), or are studying the factors for port competitiveness (Acosta, Coronado and Del Mar Cerban, 2011). Fleming and Baird (1999) identified the factors for port competition and selection with focus on improving port competitiveness. Also, some studies on port competitiveness (Cullinane, Teng and Wang, 2005; Yeo and Song, 2006) are titled port competition, reflecting the purpose of improving port competitiveness. There are also studies on evaluating port competitiveness among the ports that not having competitive relationship (Huang et al., 2003; Song and Yeo, 2004). This regrouping also reflects the relationship between port competition and competitiveness.

2.5 Discussions and Research findings

The research with identifying overlapping topic areas and the regroupings of 6 papers provide us a direction on studying the relationship among port competition, cooperation and competitiveness. Their relationships are summarized below and depicted in Figure 2-3.

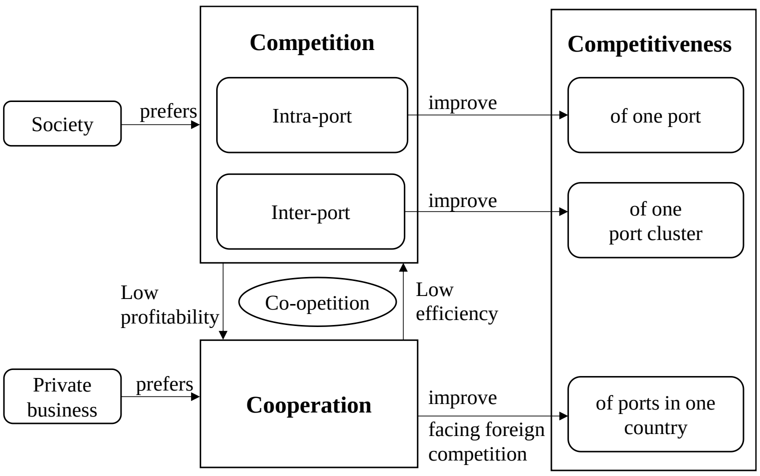


Figure 2-3 Relationships among port competition, cooperation and competitiveness

Competition and cooperation are two most important operation strategies that exist at every level of port industry, from within a port, among the ports in the same region, to between port clusters in the same country, and that from different countries. The adoption of different strategies at each level can have direct implication on the private interest of the port operators, as well as on the public interest of the hosting community. Private port operators would naturally prefer no or less competition, as it could provide them with higher-than-normal profit. However, competition is unavoidable in today's port environment. From social perspective, it is desirable to have nearby ports performing similar services in overlapping hinterland to compete, while for those working together in the same maritime supply chain to cooperate (Song, 2002; Óscar Álvarez-SanJaime et al., 2015). However, when the competition ports of one region facing new competition from the others, whether they should cooperate is often a concern (Yuen, Zhang and Cheung, 2012; Zhou, 2015). Most of the time, the preference for competition is originated from the public interest in maximum economic efficiency, while the consideration for cooperation, even integration, is often steamed from the interest of port operators (Xing, Liu and Chen, 2018). When the level of competition is too high to enable any positive profits for the private businesses, the voice for more cooperation will emerge. However, if the level of cooperation in regional ports is high enough to form market power, the concern for low efficiency will encourage more competition. Sometimes, instead of adopting only one strategies, ports can adopt the strategy of co-opetition, which allows the competing ports to cooperate on some activities that are beneficial to both (Song, 2003), such as cooperative marketing and sourcing, sharing of personal and equipment. But they still need to compete for the limited customers. Therefore, they are essentially still in competitive relationship. The real cooperation between two previously competing ports is rare.

Regarding to the relationship of port competition and competitiveness, it is widely viewed that intra-port competition can promote innovation and efficiency of a port, thus can increase the competitiveness of the port (De Langen and Pallis, 2006). For two ports serving the same hinterland, the port with higher competitiveness can out-perform the other in the inter-port competition. Operating in such an environment, a port must be competitive in order to be successful. Such competition can also increase the overall efficiency of the port cluster (De Oliveira and Cariou, 2015). Hence, the enhancement of port competitiveness can improve a port position in competition with other ports. Therefore, many papers studied port competition from the competitiveness of the port (Cullinane, Teng and Wang, 2005; Yeo and Song, 2006).

On the relationship between port cooperation and competitiveness, we found the cooperation among adjacent ports can improve their competitiveness when they are facing a new competitor from outside (Hwang and Chiang, 2010). This enhancement in the competitiveness may further encourage cooperation of these two ports. These may be the rational for the Chinese government to promote the port horizontal integration (Dong, Zheng and Lee, 2018). The "One Province One Port Group" policy can promote the cooperation among the ports in the same province, and competition among the ports in different provinces.

2.6 Chapter summary

This article reviewed the publications on port competition, cooperation and competitiveness from 1970 to 2019. All the papers are grouped into three topic areas with a summary of their respective research topics and methods. The relationship among these three areas are identified and summarized based on the studies with overlapping topic areas.

With the development of transportation technology, a seaport is no longer isolated with other ports in maritime transportation network, and when port hinterland expands, competition between ports will naturally happen. Then, how to promote port competitiveness and whether cooperation is a better strategy are important in both industry and academic studies. As the review indicates, many topics have been studied on port competition, cooperation and competitiveness using different methods, but relatively few on the relationship among these three topic areas. Current research on the relationship between port competition and cooperation includes describing the competition and cooperation relations among ports in a region, identifying better strategy for port (cooperate/compete) when facing different circumstances. Some proposed co-opetition for ports to better cope with the changing port environment. However, most of the studies are studying from the perspective of ports, few evaluated the implication of these strategies from different perspectives, especially from social point of view. On the relationship between port competition and competitiveness, many studied how internal competition can help to keep external competitiveness, such as intra-port competition to port competitiveness. Logically, it is reasonable to believe that inter-port competition can also help the ports to improve their collective competitiveness when they are facing external competition. However, many studies concluded that it is better to cooperate, rather than compete, when they are facing external competitors. Why intra-port comport competition can increase the competitiveness of the port, while port cooperation can enhance the competitiveness of the port region/cluster? If internal competition is a better strategy, how to maintain investors' interests if a higher level of competition results in a low profit margin? If cooperation is a preferred one, then how to prevent the possible inefficiency when the level of competition is not enough?

The answers to these questions are very important to the policies in port development and management, especially for China, as many coastal ports are actively following the government policy for "One Province One Port Group". The horizontal integration of the coastal ports in one Province may increase the market power of the port groups in the hosting province, which may reduction in level of competition for the cargoes in the province and create inefficiency. However, considering that China has a long Coastal line where there are many provinces hosting seaports, if there is competition among these port groups, it could also be beneficial to the competitiveness of its national port system. Therefore, it is very important to balance the benefits and possible negative impacts of port horizontal integration in the “One Province One Port Group” policy. This requires further study on the relationship among these topic areas. Having identified the existing research on the relationship among port competition, cooperation and competitiveness, this paper is strived to be a steppingstone for the further research on these important issues.

Chapter 3 Port strategy considering port attribute and shippers' preference: analyzing port integration in China

Through reviewing the relevant literature on the relationships among port competition, cooperation, and competitiveness, it is known that internal competition within a port can improve port efficiency and thus enhance port competitiveness. When adjacent ports face external competition, cooperation between them can increase the overall competitiveness of the port cluster. In addition, some scholars proposed port integration and encouraged various forms of cooperation among ports to improve port operational efficiency. Especially, Chinese government initiated the port integration policy-One Province One Port Group to encourage cooperation among the ports in the same region. Therefore, this chapter analyzes whether two ports should cooperate and whether the port integration policy is necessary considering both external and internal conditions of the ports. An analytical model is established to analyze the impacts of these conditions on ports, shippers and social welfare, and a numerical simulation is conducted to illustrate the results. The results show that ports prefer cooperation as it can generate higher profit. For complementary ports, cooperation should be encouraged as it can generates higher social welfare. For substitutable ports, competition is better and should be promoted. Cooperation between substitutable ports can lead to monopoly, resulting in low social welfare. This loss increases with the level of overcapacity compared with competition. Hence cooperation should be prevented in this case.

3.1 Introduction

Over the past twenty years, seaports have been developed rapidly due to the increase of international trade and global logistics. Seven out of the ten busiest container ports in the world are Chinese ports (Nguyen et al., 2020). The huge benefits of port development to the local economy motivated many coastal cities to expand their ports and make them the hub ports of the region or the country. However, with the slowdown of Chinese economy, it created serious overcapacity, intensified competition, and made it difficult for the port/terminal operators to stay profitable. Especially, with the increasing bargaining power from shipping alliances, many port operators voiced for more cooperation to reduce or avoid price undercutting(Yang, Luo and Wu, 2022). Chinese government also initiated port integration policy, such as the “One Province One Port Group” (Cheng, Lian and Yang, 2022), to encourage cooperation, reduce competition and ensure an efficient use of port resources(Dong, Zheng and Lee, 2018; Guo, Yang and Yang, 2018; Yang, Guo and Lian, 2019; Ma et al., 2021). Such policy has been adopted by many municipalities and provinces, including Liaoning, Jiangsu, Shanghai, Zhejiang, Fujian and Guangxi, covered all coastal areas in China.

From the perspective of port operators, competition and cooperation are two commonly used strategies to gain more profit and improve competitiveness to attract both investors and customers. Usually, they are two concepts that port researchers used to describe the relationships of the ports serving in an overlapping hinterland. However, such relationships are determined not only by the ports, but also by the port users (shippers or carriers). Users’ preference—the external condition of the ports—determines whether the service provided by the two ports is substitutable or complementary. Ports can only decide whether they maximize joint or individual profits. The former is usually termed as cooperate (CO), while the latter is named as Non-cooperate (NC). Competition is a special case of NC where the service provided by the two ports is substitutable.

From the perspective of the government, the interests of ports and shippers are equally important. With the slowdown of China’s economic growth, integration has been put forward by government to reduce overcapacity and excessive port competition. Up to now, many Provinces have adopted a pattern of “one Province one port group” to integrate their port resources, including Liaoning, Jiangsu, Zhejiang, Fujian and Guangxi, the integration of China’s port resources has basically covered all coastal provinces from north to south. Port integration have become the mainstream trend of port development in the future, integrating port resources effectively, increasing focus on seaport integration and cooperation, adopting appropriate strategies for ports also have become hot topics(Song and Panayides, 2002; Panayides and Song, 2009; Wang, Ducruet and Wang, 2015; Yang, Guo and Lian, 2019; Yang, Luo and Wu, 2022). Therefore, the objective of a government policy should be to maximize social welfare, which is the total benefits of ports and shippers. However, the ports in a region could have different internal conditions—they can be overcapacity or congested. Then, is government policy necessary in all the combination of these internal and external conditions? How much difference it can make compared with no policy, i.e., allow port operators to decide their best strategies? If no policy is implemented, which one is better, CO or NC?

Therefore, this study analyzes and compares the impacts of port internal and external conditions on market price, quantity, consumer and producer surpluses, and social welfare when two ports are operating in CO or NC, with that of social welfare maximization (SO). The results are summarized as follows. First, for complementary ports, CO is better from social perspective as it generates lower price and higher quantity, consumer surplus and social welfare compared with NC. For substitutes, NC is better. Therefore, CO should be encouraged for complementary ports, while NC is better if they are substitutes. This confirms with the double marginalization theory in the vertically integrated supply chain(Hamilton and Ibrahim, 1996). However, as a private operator, port always prefer CO as it can generate higher profit. Thus, public policy is not necessary if it is just to encourage cooperation. It is only required when the port services are substitutes, to encourage competition and prevent monopoly. Second, comparing the benefits distribution between shippers and ports, in CO, when the change in marginal cost is less than the change in marginal utility for one unit of cargo handled, the shippers can benefit more than the ports. This only happens when the ports are in overcapacity. In NC, if the change in marginal cost is less than the change in marginal utility with the substitution/complementary effects, the shippers can also benefit more than the ports. This could happen when the ports are in overcapacity or congested. When ports are in overcapacity, the gap in consumer surplus between CO and NC is big. Therefore, which strategy to take is critical for shippers.

The main contributions of this study are as follows:

i. This is the first research that compares the NC and CO under different combinations of port attribute and shippers' preference. Compared with the existing research that are focused on competition and cooperation in specific environment, this study provides a more general case where different degree of complementarity/substitutability and overcapacity/congestion are put in one framework. This could benefit the policy for regional port management, as there are always ports with different operational status and shippers' preference in a region.

ii. Government policy should be designed to maximize the total benefits to ports and shippers. If the "port integration" policy is just to promote cooperation among ports, it is not necessary. There will be a social welfare loss if ports are cooperating rather than competing when the port services are substitutes, and such loss can increase with the level of substitutability.

iii. Overcapacity is inevitable due to the aggressive port development in the past and the current slowdown of world trade. For ports providing substitutable services, the competition will naturally higher. The key to solve this problem is to reduce capacity, not to encourage cooperation—such as the "One Province One Port Group" policy. As pointed out by this research, such cooperation can form monopoly and reduce social welfare.

The remainder of this study is organized as follows. In Section 3.2, we present a literature review of relevant studies. In Section 3.3, we design analytical models to identify the equilibrium outcomes CO and NC, together with that of SO. Section 3.4 gives a comparative analysis of the equilibrium results among the three cases. Numerical examples are presented in Section 3.5, followed by discussion and conclusions. Section 3.6 provides a discussion and policy implication for the propositions and numerical simulation results. Summary and conclusions are provided in Section 3.7.

3.2 Literature review

Most of the studies on port competition or cooperation are motivated by the needs of port operation or development strategies in a specific environment. This environment is often pre-defined, which does not require the researcher to consider all the possible relationships among the players in the problem.

Game theoretical-model are often used to study the strategies for port operation and development strategies when the ports are in a competitive environment (Luo, Liu and Gao, 2012; Anderson et al., 2008; Ó Álvarez-SanJaime et al., 2013; Ishii et al., 2013; Zhang et al., 2018). For example, Anderson et al. (2008) developed a game-theoretical model to analyze competition for container hub ports between Busan and Shanghai, to decide whether it is the best strategy to expand the capacity in Busan. Luo, Liu and Gao (2012) analyzed port competition between Shenzhen and Hong Kong using a two-stage game model, to decide whether port expansion in Hong Kong can be profitable when Shenzhen port is expanding fast. Wan, Basso and Zhang (2016) analyzed the impact of accessibility on port competition, to determine the investment strategies in port accessibility. Similar studies include Haralambides (2002) and Borger and Dender (2006), which investigated inter-port competition considering capacity expansion or investment. Ishii et al. (2013) constructed a non-cooperative game theoretic model to investigate port competition with the strategy of selecting port charges under uncertainty, and they deduced the Nash equilibrium and obtained some propositions with the case of Busan port and Kobe port. In these studies, the application environment is predetermined: competitive. Most of time, game theory model will be adopted and the means for competition is pricing. These studies are focused on the specific market condition and port attributes, and possible strategies in different market and port attributes are not provided.

There are also many studies described the regional port competition and cooperation relationship, such as those in Hong Kong(Song, 2002, 2003; Wang et al., 2012; Wang and Liang, 2022), Liaoning(Ma and Qian, 2011; Xiao and Liu, 2017), Chile(Trujillo, Campos and Pérez, 2018), Japan(Shinohara and Saika, 2018; Inoue, 2018), Rotterdam(Castelein, Geerlings and Van Duin, 2019), the Netherlands(Donselaar and Kolkman, 2010). The purposes of these studies are often to identify the driving factors for competition-cooperation relationships (Castelein, Geerlings and Van Duin, 2019), investigate the impacts of port cooperation/competition strategies on port investment or operation policy (Donselaar and Kolkman, 2010; Wang and Zhang, 2018). There are also literatures analyzing the best strategy for ports (cooperate or compete), such as Zhou (2015) analyzed the best strategy (competition or cooperation) of multiple ports serving the same hinterland using modified Hoteling model, the results indicated that if service levels of the three ports are the same, the optimal price of the port located at the middle of them is lower, and in order to capture greater market share, ports are motivated to form cooperation. Xing, Liu and Chen (2018) analyzed port competition and cooperation between two neighbor ports with a third port sharing the same overlapping hinterland considering the inland transportation cost and port pollution, and the results revealed that the uniform pricing generates higher green social welfare when both inland transportation cost and pollution are relatively low. Zheng and Luo (2021) investigated the strategies of ports when facing the increasing bargaining power of shipping alliances with a dynamic game model, they considered the shipping lines' economies of scale and substitutability, and the results revealed that the ports' vertical cooperation is the best for both the local social welfare and the social welfare mostly. Actually, the port relations are determined not only by the ports, but also by the port users (shippers). The demand is determined by the users based on the service provided by the ports, and such relationship can be substitutes or complements with different degrees. In our study, NC is general, where two ports can serve in the same hinterland or different hinterland, the service provided by them can be substitutes or complements, each port just decide its respective price to its own interest. In "port cooperation", they determine their prices jointly to maximize total profit.

Previous studies on port cooperation and integration always take many different forms, the basic form of cooperation are horizontal cooperation and vertical cooperation (Li and Oh, 2010; Hoshino, 2010; Huo, Zhang and Chen, 2018; Zheng and Luo, 2021). Often, the word "integration" is used interchangeably with "cooperation". Ryoo (2011) pointed out that port cooperation can be formal or informal, and horizontal or vertical based on port cooperative activities. With the slowdown of economic growth rate and competition intensifies, a great number of studies that analyzing port cooperation or integration has emerged. For example, Saeed and Larsen (2010) used a two-stage game theoretical model to analyze the possible cooperation among three container terminals located in Karachi Port in Pakistan, and found that it could result in a higher price. This is expected as cooperation can increase the market power. However, Dong, Zheng and Lee (2018) constructed a three-stage noncooperative game model to analyze the effects of regional port integration, and they found that integration can reduce the marginal cost of both ports, and higher degree of regional port integration can cause lower handling charge and greater container throughput in the model due to their assumption. The integration used in this paper is just cooperation where the members intended to maximize total profit. Guo, Yang and Yang (2018) and Yang, Guo and Lian (2019) investigated the integration method in a multi-port region by considering multi-period investment and idle assets based on social welfare maximization. These studies provided suggestions and policies that favor the port integration/cooperation in multi-port regions. However, the definition of integration is not provided, and it appears the same as cooperation. In practice, port cooperation is motivated by port operators based on their common interests. Integration is a term steamed from supply chain management, such as horizontal or vertical integration. From economics' point of view, such integration is just cooperation. In our study, port integration is regarded as a government policy, which should include the benefits of both ports and shippers.

As outlined above, previous studies relate to port competition and cooperation mainly focused on the ports serving the same overlapping hinterland, and the demand function is always given directly. In addition, the theoretical studies on port cooperation and integration rarely considered port users' benefit, and few distinguished the difference between the two strategies. Therefore, differentiate to previous studies, we begin from the utility function, considering the interests of both ports and shippers, in different market conditions (overcapacity or port congestion), different port relationship viewed by port users (substitute or complement) to compare the properties of "port competition", "port cooperation" and "port integration" under the same environment, to identify the best strategies of ports. From port operator's perspective, we consider a duopoly market where each port decides its own best price to maximize individual profit (NC), or determine their prices jointly to maximize total profit (CO), the former is named "port competition", while the latter is called "port cooperation" in our study. From social perspective, we maximize social welfare (SO) to obtain the optimal price of each port, and this is the third strategy "port integration". Previous studies relate to port competition and cooperation mainly focused on a predetermined environment, such as the ports serving the overlapping hinterland, providing substitutable services, or which strategy they should choose when the shippers' preference changes. In this study, all potential combinations of port attribute and shippers' preference are considered in determining the best strategy of the ports (non-cooperate, cooperate) and that for society.

3.3 The model

To simplify the analytical modelling, we assume that two ports, providing cargo loading/unloading services in a region, are considering whether they should cooperate (CO) or not (NC), i.e., to maximize joint profit (CO) or individual profit (NC). The government policy should maximize social welfare (SO). Therefore, CO and NC are motivated from private business operations, and SO is from social perspective, which is provided as a benchmark.

The utility function of the shippers is assumed to be quadratic with the quantity of port services (q_1 and q_2) provided by two ports, and the composite good m, following Singh and Vives (1984):

$$U(q_1, q_2) = a(q_1 + q_2) - b({q_1}^2 + 2\theta q_1 q_2 + {q_2}^2)/2 + m, \tag{3-1}$$

where $a > 0$ and $b > 0$ are the parameters that should enable positive marginal utility, i.e., $\frac{\partial U(\cdot)}{\partial q_1} = a - bq_1 - b\theta q_2 > 0$ and $\frac{\partial U(\cdot)}{\partial q_2} = a - bq_2 - b\theta q_1 > 0$. $|\theta| < 1$ defines the relationship between the two ports. If $\theta < 0$, they are complements, such as the relationship between a feeder port and a hub port; If $\theta > 0$, they are substitutes. If it is equal to 0, the services provided by the two ports are not related. The parameter m can be looked upon as the numeraire in the budget constrain of the consumer, representing the total expenditure on all other goods, i.e., $m = I - p_1q_1 - p_2q_2$. Such utility function implies the liner demand functions for the services at the two ports:

$$q_1 = \left(a - \frac{1}{1-\theta}p_1 + \frac{\theta}{1-\theta}p_2\right)\frac{1}{\mu}, \text{ and } q_2 = \left(a - \frac{1}{1-\theta}p_2 + \frac{\theta}{1-\theta}p_1\right)\frac{1}{\mu}. \quad (3\text{-}2)$$

where $\mu = b(1+\theta) > 0$ is the reduction in marginal utility for a unit increase of the service at both ports. If they are substitutes ($\theta > 0$), the reduction is much bigger than if they are complements.

On the cost side, we used a general quadratic cost function for each port as follows,

$$C(q_i) = cq_i + \frac{\lambda q_i^2}{2},\ i\epsilon\{1,2\}. \quad (3\text{-}3)$$

where q_i denotes the total cargo handling services provided by port i, λ the cost factor representing whether the port is in overcapacity ($\lambda < 0$), congestion ($\lambda > 0$), or constant return to scale ($\lambda = 0$). Since it reflects the operation status of the port, it is used as the port capacity. $c > 0$ is the marginal and average cost when $\lambda = 0$.

3.3.1 Analytical modeling of the equilibrium price, quantity and social welfare

In this section, we model the equilibrium prices and quantities of two ports in three strategies: “port competition (NC)”, “port cooperation (CO)”, or “port integration (SO)”, and their corresponding total profits, consumer surplus and social welfare.

In NC, each port decides its best price to maximize its individual profit, i.e.,

$$\max_{p_i} \pi_i = p_iq_i - \left(cq_i + \frac{\lambda q_i^2}{2}\right), \text{ for } i\epsilon\{1,2\}. \quad (3\text{-}4)$$

To ensure profit maximization, the second order condition (SOC) should be satisfied, i.e., $-\frac{1}{(1-\theta)\mu}\left(2+\lambda\frac{1}{(1-\theta)\mu}\right)<0$. Since $\frac{1}{(1-\theta)\mu}>0$, it requires $2\mu(1-\theta)+\lambda>0$, i.e., $\lambda>-2b(1-\theta^2)$, as $\mu=b(1+\theta)$. From the first order conditions (FOCs), the optimum equilibrium prices of the two ports can be obtained:

$$p_i^{NC}=\frac{\mu[a(1-\theta)+c]+\lambda a}{\mu(2-\theta)+\lambda}, \qquad i\in\{1,2\}. \tag{3-5}$$

Then, the equilibrium quantity for each port can be written as:

$$q_i^{NC}=\frac{(a-c)}{\mu(2-\theta)+\lambda}. \tag{3-6}$$

And the consumer surplus $CS=U(q_1,q_2)-p_1q_1-p_2q_2$, total profit $\Pi=\pi_1+\pi_2$, and social welfare $SW=CS+\Pi$ can also be formulated as:

$$CS^{NC}=\frac{\mu(a-c)^2}{(\mu(2-\theta)+\lambda)^2}+m,\ \Pi^{NC}=\frac{[2\mu(1-\theta)+\lambda](a-c)^2}{(\mu(2-\theta)+\lambda)^2},$$
$$SW^{NC}=\frac{[\mu(3-2\theta)+\lambda](a-c)^2}{(\mu(2-\theta)+\lambda)^2}+m. \tag{3-7}$$

In CO, the two ports will adjust their respective prices to maximize joint profit. Then the objective function is:

$$\max_{p_1,p_2}(\pi_1+\pi_2)=\sum_{i=1}^{2}\left(p_iq_i-cq_i-\frac{\lambda q_i^2}{2}\right). \tag{3-8}$$

The SOC requires $\lambda>\frac{-2b(1-\theta^2)}{(1+\theta^2)}$ and $\lambda>-2b(1+\theta)$.

In SO, as it is initiated by the government, it should not only consider the benefit of the port operators, but also the shippers. Therefore, the objective should be to adjust the prices of the two ports to maximize the total social welfare (SO), i.e.,

$$\max_{p_1,p_2} SW=U(q_1,q_2)-\sum_{i=1}^{2}(cq_i+\lambda/2q_i^2). \tag{3-9}$$

The SOC for this problem requires $\lambda > \frac{-b(1-\theta^2)}{(1+\theta^2)}$ and $\lambda > -b(1+\theta)$.

Comparing the three SOCs, when $\theta = 0$, the minimum requirements for λ in NC and CO are the same ($-2b$), which is lower than that in SO ($-b$). When $|\theta| \to 1$, $\lambda \to 0-$. In addition, compare the two conditions in SO, $\frac{-b(1-\theta^2)}{(1+\theta^2)}$ >/< $-b(1+\theta)$ if θ >/< 0. The SOC in CO is just twice of that in SO. Thus, the first SOC in CO or SO is binding when θ is positive, and the second one is when θ is negative. From this, when the ports have excessive capacity, the SOC for social welfare maximization may be not possible to satisfy, but it is still possible for private operators to maximize profit (jointly or individually).

The equilibrium prices in CO and SO can be obtained using their respective FOCs, and the quantity, profit, consumer surplus and social welfare can also be figured out accordingly. They are listed in Table 3-1.

Table 3-1 The equilibrium outcomes in SO, NC, CO

	SO	NC	CO
p_i^*	$\frac{c\mu+\lambda a}{\mu+\lambda}$	$\frac{\mu[a(1-\theta)+c]+\lambda a}{\mu(2-\theta)+\lambda}$	$\frac{\mu(a+c)+\lambda a}{2\mu+\lambda}$
Q^*	$\frac{2(a-c)}{\mu+\lambda}$	$\frac{2(a-c)}{\mu(2-\theta)+\lambda}$	$\frac{2(a-c)}{2\mu+\lambda}$
Π^*	$\frac{\lambda(a-c)^2}{(\mu+\lambda)^2}$	$\frac{[2\mu(1-\theta)+\lambda](a-c)^2}{[\mu(2-\theta)+\lambda]^2}$	$\frac{(a-c)^2}{2\mu+\lambda}$
CS^*	$\frac{\mu(a-c)^2}{(\mu+\lambda)^2} + m$	$\frac{\mu(a-c)^2}{[\mu(2-\theta)+\lambda]^2} + m$	$\frac{\mu(a-c)^2}{(2\mu+\lambda)^2} + m$
SW^*	$\frac{(a-c)^2}{\mu+\lambda} + m$	$\frac{[\mu(3-2\theta)+\lambda](a-c)^2}{[\mu(2-\theta)+\lambda]^2} + m$	$\frac{(3\mu+\lambda)(a-c)^2}{(2\mu+\lambda)^2} + m$

Note: $Q^* = q_1^* + q_2^*$

From this table, it can be easily seen that:

- when there is no congestion or overcapacity ($\lambda = 0$), the equilibrium price in SO is just equal to the marginal cost.

- When two services are not related ($\theta = 0$), NC and CO can result in the same price and quantity, which has a higher price and lower quantity than the SO case.

However, when λ and θ are not equal to zero, the relative prices in three strategies are different, which will be shown next.

Based on the above conclusion, we further analyze the condition for consumer surplus be higher than port profit. Based on the equilibrium outcomes in Table 3-1, it is straightforward to obtain:

$$CS^{CO} \geq \Pi^{CO} \; if \; \lambda \leq -\mu \tag{3-10a}$$

$$CS^{NC} \geq \Pi^{NC} \; if \; \lambda \leq -\mu(1-2\theta) \tag{3-10b}$$

Since μ is the reduction in marginal utility for each unit of port throughput, and it is always positive, both equations indicate that consumers prefer a lower equation (3-10a) can only be true if λ is negative, i.e., ports are in overcapacity. In this case, for one unit increase in the port output, it can decrease marginal cost by λ. If the decrease in marginal cost is less than the increase in utility ($-\mu$), consumer surplus will be larger than port profit.

In the NC case, due to the individual profit maximization behavior, the right-hand side is adjusted by $1-2\theta$. When $\theta < 0$, one unit's port service can contribute more to the consumer utility due to the complementary effect. Therefore, it requires a larger overcapacity to make consumer surplus higher. When it is positive, the contribution to utility is smaller due to substitution. If $\theta > \frac{1}{2}$, $\lambda > 0$, indicating that if the services provided by the two ports are similar, consumer surplus can be higher than port profit even there is congestion. Therefore, from shippers' point of view, competition is better if two ports have a high similarity. In either case, reducing the value of λ is always good for shippers.

3.3.2 Comparative statics analysis of equilibrium outcomes w.r.t. λ and θ

The equilibrium outcomes in section 3.1 rest on the external condition of the two ports (θ), and the internal condition (λ). In this section, we analyze how these outcomes change with λ and θ respectively using comparative statics. The results are shown in Table 3-2.

From this result, it can be seen that the increase of λ, whether it is the reduction in the magnitude of overcapacity ($\lambda < 0, |\lambda|$ decrease), or increase in congestion factors ($\lambda > 0$), can push up the equilibrium price, reduce quantity, consumer surplus and social welfare. Therefore, to reduce competition when there are over capacity ($\lambda < 0$), it is better to reduce capacity, as it can reduce the level of overcapacity (lower $|\lambda|$), increase price. If two ports adopt CO, their total profit can decrease. For the SO case, the total profit of the two ports can increase or decrease depends on relative magnitude between the change in marginal utility (μ) and the change in marginal cost (λ). In the NC case, it depends on the sign of $\mu(2-3\theta)+\lambda$.

Table 3-2 Comparative statics analysis for the equilibrium results *w.r.t.* λ and θ.

	w.r.t. λ			*w.r.t.* θ		
	NC	CO	SO	NC	CO	SO
p_i^*	+	+	+	-$sgn(\lambda+\mu(1+\theta))$	-$sgn(\lambda)$	-$sgn(\lambda)$
Q^*	-	-	-	$sgn(\theta-\frac{1}{2})$	-	-
Π^*	$sgn(\lambda+\mu(2-3\theta))$	-	$sgn(\mu-\lambda)$	-	-	-$sgn(\lambda)$
CS^*	-	-	-	-$sgn(3\mu\theta+\lambda)$	$sgn(\lambda-2\mu)$	$sgn(\mu-\lambda)$
SW^*	-	-	-	-$sgn(\mu(4\theta^2-7\theta+4)+\lambda)$	-	-

Note: $sgn(x)$ stands for the sign of the variable x.

The comparative statistics *w.r.t.* θ is more complicated:

- On the equilibrium prices of CO and SO, if congestion exists ($\lambda > 0$), the increase in θ can reduce the prices. If overcapacity exists ($\lambda < 0$), the price can increase. In NC, only when $\lambda + \mu(1+\theta) < 0$, the price will increase. Therefore, when there are congestions, increase service similarity among the two ports can reduce the market price. When there is overcapacity, increase similarity can result in higher price in CO or SO. For NC case, if marginal utility is less than the weighted average marginal cost, i.e., $\mu < -\frac{\lambda}{1+\theta}$, price will decrease.
- On the equilibrium quantity, the increase in service similarity reduces total output. However, in NC cases, if the similarity is high enough, it can increase their outputs.
- Generally, the impact of increasing service similarity on social welfare is negative for all the cases. Only if $\mu(4\theta^2 - 7\theta + 4) + \lambda < 0$, i.e., when $\lambda < 0$, it is possible that the impact is positive in NC.

3.4 Comparison of the equilibrium results among three cases

This section compares the equilibrium price, quantity, total profit, consumer surplus and social welfare of NC, CO and SO strategies. We first state the conclusion and significance of the comparison, then proof of such results. All the conclusions are made by pair-wise comparison of the equilibrium outcomes among three cases as listed in Table 3-1.

Proposition 1. $p_i{}^{so} < min(p_i{}^{CO}, p_i{}^{NC})$; $p_i^{NC} >/=/< p_i^{CO}$ if $\theta </=/> 0$ ($i\epsilon\{1,2\}$).

This proposition states that the equilibrium price in SO is always the lowest. As the purpose is to maximize social welfare, the optimal price should be lower, to incorporate the benefits of the consumers. When the service of the two ports are complements ($\theta < 0$), the price in CO is always lower than that NC; when they are substitutes, the price in CO is always higher than that in NC. When they are not related ($\theta = 0$), the prices of the two cases are equal. Therefore, if one is a hub port and the other is a feeder, NC will result in a higher price, thus CO is a preferred strategy. If two ports provide similar services, NC is a better strategy. If two ports provide different services, such as a container port with a dry-bulk one, their strategies do not matter. This conclusion can be obtained by pair-wise comparison of the equilibrium prices. Since $\mu > 0$, $-1 < \theta < 1$, $a > c$:

$$p_i^{NC} - p_i^{CO} = \frac{-\mu^2 a\theta}{[\mu(2-\theta)+\lambda](2\mu+\lambda)} >/=/< 0 \text{ if } \theta </=/> 0, \tag{3-11a}$$

$$p_i^{CO} - p_i^{SO} = \frac{\mu^2(a+c)}{(2\mu+\lambda)(\mu+\lambda)} > 0, \tag{3-11b}$$

$$p_i^{SO} - p_i^{NC} = \frac{-\mu^2(1-\theta)(a-c)}{(\mu+\lambda)[\mu(2-\theta)+\lambda]} < 0\ . \tag{3-11c}$$

since all the denominators are positive according to the SOCs.

Proposition 2. $Q^{SO} > max(Q^{NC}, Q^{CO})$; $Q^{NC} </=/> Q^{CO}$ if $\theta >/=/< 0$.

The total throughput in SO is always the highest due to its lowest price compared with NC and CO. Comparing the quantity in NC with that in CO, when the two ports are complements ($\theta < 0$), the total throughput in NC is lower, as its price is higher. When they are substitutes ($\theta > 0$), the total throughput in NC is higher. Proposition 2 can be proved by comparing the pair-wise optimal total output Q^* in Table 3-1:

$$Q^{NC} - Q^{Co} = \frac{2\mu\theta(a-c)}{[\mu(2-\theta)+\lambda](2\mu+\lambda)} >/=/< 0 \text{ if } \theta >/=/< 0, \tag{3-12a}$$

$$Q^{CO} - Q^{SO} = \frac{-2\mu(a-c)}{(2\mu+\lambda)(\mu+\lambda)} < 0, \tag{3-12b}$$

$$Q^{NC} - Q^{SO} = \frac{-2\mu(1-\theta)(a-c)}{[\mu(2-\theta)+\lambda](\mu+\lambda)} < 0. \tag{3-12c}$$

Proposition 3. $\Pi^{SO} < \Pi^{NC} < \Pi^{CO}$.

Proposition 3 states that the total profit of two ports in CO is always the highest followed by NC, and SO always has the lowest total profit. As the objective of CO is to maximize total profit and that for NC is to maximize individual profit, the former is naturally higher. The total profit in SO is always the lowest, as its objective is to maximize the social welfare which includes the benefits of both ports and consumers. Proposition 3 can be proved as follows:

$$\Pi^{NC} - \Pi^{CO} = \frac{-\mu^2\theta^2(a-c)^2}{[\mu(2-\theta)+\lambda]^2(2\mu+\lambda)} < 0, \tag{3-13a}$$

$$\Pi^{CO} - \Pi^{SO} = \frac{b^2(1+\theta)^2[2\mu+\lambda](a-c)^2}{(2\mu+\lambda)^2(\mu+\lambda)^2} > 0, \tag{3-13b}$$

$$\Pi^{NC} - \Pi^{SO} = \frac{\mu^2(1-\theta)[2\mu+\lambda(1+\theta)](a-c)^2}{[\mu(2-\theta)+\lambda]^2(\mu+\lambda)^2} > 0. \tag{3-13c}$$

Proposition 4. $CS^{SO} > max(CS^{CO}, CS^{NC})$; $CS^{CO} </=/> CS^{NC}$ if $\theta >/=/< 0$.

Proposition 4 reveals that SO provides the highest consumer surplus, as it is one part of the objective function. When the two ports are complements, $\theta < 0$, CO can provide higher benefits to consumers as it has lower price and higher output. If they are substitute, NC has lower price and higher output, and therefore higher consumer surplus. From this result, we can find that NC strategy is not always the best choice to benefit the consumers compared with CO. The proofs are shown below.

$$CS^{NC} - CS^{CO} = \frac{[\mu(2-\theta)+2(\lambda+\mu)]\mu^2\theta(a-c)^2}{[\mu(2-\theta)+\lambda]^2(2\mu+\lambda)^2} </=/> 0 \text{ if } \theta </=/> 0, \tag{3-14a}$$

$$CS^{CO} - CS^{SO} = \frac{-b^2(1+\theta)^2(3\mu+2\lambda)(a-c)^2}{(2\mu+\lambda)^2(\mu+\lambda)^2} < 0, \tag{3-14b}$$

$$CS^{NC} - CS^{SO} = \frac{-[2(\mu+\lambda)+\mu(1-\theta)]\mu^2(1-\theta)(a-c)^2}{[\mu(2-\theta)+\lambda]^2(\mu+\lambda)^2} < 0. \quad (3\text{-}14c)$$

Proposition 5. $SW^{SO} > max(SW^{CO}, SW^{NC})$; SW^{CO} >/=/< SW^{NC} if θ </=/> 0.

Here SW naturally generates the highest social welfare, as it is its objective. Neither CO nor NC can maximize social welfare, regardless their relationship (complements or substitutes). Compared with NC, CO can provide a higher social welfare when two ports are complements, as it generates lower price and higher quantity. If they are substitutes, NC is better, but not as high as SO. This result can be verified by comparing their social welfare:

$$SW^{NC} - SW^{CO} = \frac{\mu^2\theta[(\mu+\lambda)(2-\theta)+2\mu(1-\theta)](a-c)^2}{[\mu(2-\theta)+\lambda]^2(2\mu+\lambda)^2} >/=/< 0 \text{ if } \theta >/=/< 0, \quad (3\text{-}15a)$$

$$SW^{NC} - SW^{SO} = \frac{-\mu^2(\mu+\lambda)(1-\theta)^2(a-c)^2}{[\mu(2-\theta)+\lambda]^2(\mu+\lambda)^2} < 0, \quad (3\text{-}15b)$$

$$SW^{CO} - SW^{SO} = \frac{-\mu^2(\mu+\lambda)(a-c)^2}{(2\mu+\lambda)^2(\mu+\lambda)^2} < 0. \quad (3\text{-}15c)$$

From this, in terms of social welfare, NC is better if two ports are complements, but CO is better if they are substitute. A summary of the pair-wise comparison is provided in Table 3-3. From this, the relationship between the services provided by the two ports will not change the position of SO in the ranking. As it is intended maximize social welfare, the prince and total profit are always the lowest, while quantity, consumer surplus and total social welfare are highest.

In summary, for complements, compared with NC, CO can result in lower price, higher quantity, profit, consumer surplus and social welfare. For substitutes, compared with NC, CO can result in higher price and profit, lower quantity, consumer surplus and social welfare. Therefore, from the perspective of ports, cooperation is always a better choice. However, when the two ports provide substitutable services, such cooperation forms monopoly, which is not consistent from the social perspective. From social perspective, NC is better when the two ports are substitute, while CO is better when they are complements. Therefore, government intervention is required when two ports are close substitutes, to prevent monopoly and ensure higher social welfare.

Table 3-3 Summary on the results through pair-wise comparison

	$\theta > 0$ (substitutes)			$\theta < 0$ (complements)		
	NC	CO	SO	NC	CO	SO
p_i^*	2	1	3	1	2	3
q_i^*	2	3	1	3	2	1
Π^*	2	1	3	2	1	3
CS^*	2	3	1	3	2	1
SW^*	2	3	1	3	2	1

Note: The numbers in the table indicating the ranking. 1 being the highest, 3 the lowest.

3.5 Numerical analysis

In this section, numerical simulations are designed to further examine how the combination of internal and external condition affects the equilibrium price, total quantity, total profit, consumer surplus and social welfare changed in these three cases.

3.5.1 Assumption on parameter value

The focus of the numerical simulation is to illustrate the impacts of θ and λ on the equilibrium results. To simplify the simulation process, the impact of the expenditure of other goods on utility is not considered, i.e., $m = 0$. In addition, it is assumed that $a = 40$, $b = 10$, to ensure the positive marginal utility. The starting point of marginal cost, c, is assumed to be 5, to maintain a positive marginal cost ($mc_i = c + \lambda q_i > 0$). Also, to maintain a positive price, quantity, the value of the parameters λ, θ should satisfy the SOCs stated in section 3.1. When congestion exists, i.e., $\lambda > 0$, the SOCs are automatically satisfied. However, it is not true when there is overcapacity, i.e., $\lambda < 0$. Figure 3-1 plots the SOCs in the θ and λ space. From this, the SOC for NC covers the biggest area (1+2+3), and that for SO is the smallest (3). SO has no maximum when economic of scale is too big, i.e., too much overcapacity. These will be reflected in the use of specific value in the numerical simulation.

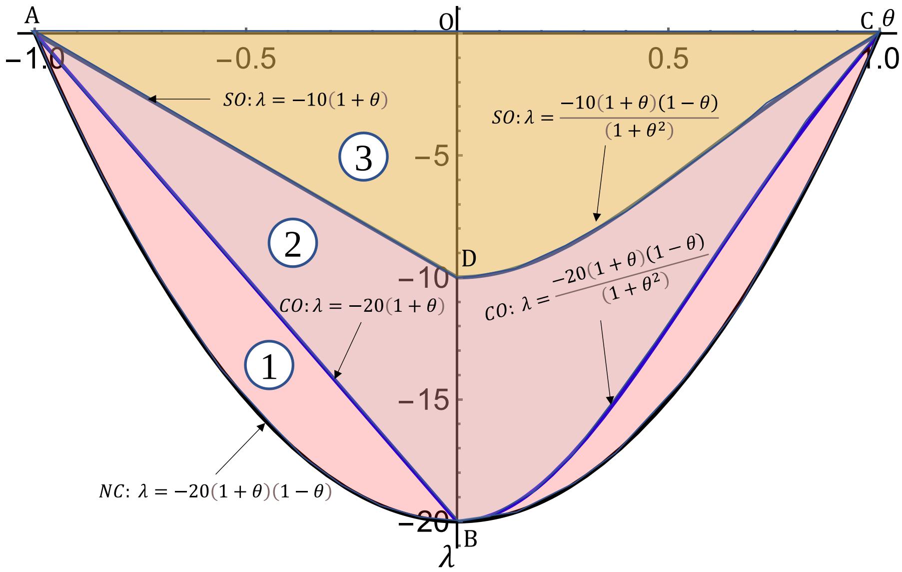


Figure 3-1 Areas that satisfy the SOC of three strategies

3.5.2 Benefit allocation between ports and shippers

First, to assess the fairness on the benefits allocation to shippers and ports, we analyze the ratio $r = \frac{\Pi}{CS}$. The ratios in these three strategies can be written as:

$$r^{NC} = 2(1-\theta) + \frac{\lambda}{b(1+\theta)},\ r^{CO} = 2 + \frac{\lambda}{b(1+\theta)},\ r^{SO} = \frac{\lambda}{b(1+\theta)}. \tag{3-16}$$

Where b is the parameter that should enable positive marginal utility, and it should have $b < a$, and $-1 < \theta < 1$ as stated the relationship between the two ports.

As analyzed in section 3.3.1, we should satisfy all the positive prices, quantities, and second order conditions (SOC) under the equilibriums in competitive, cooperative and integrative environment. Therefore, λ, θ and b should satisfy the following inequations,

NC: $\lambda > -2b(1+\theta)(1-\theta),$

CO: $\lambda > \frac{-2b(1+\theta)(1-\theta)}{(1+\theta^2)}$ and $\lambda > -2b(1+\theta)$,

SO: $\lambda > \frac{-b(1+\theta)(1-\theta)}{(1+\theta^2)}$ and $\lambda > -b(1+\theta)$. (3-17)

For a given θ and $b(b > 0)$, it is always true that λ should satisfy a specific inequation. When the congestion effect generates, $\lambda > 0$, it always satisfies the inequations, and the cost of port will increase with the increase of quantity. When the economies of scale effect generates, $\lambda < 0$, the cost of port will decrease with the increase of quantity.

To illustrate the allocation with the change of θ and λ, the lines where the ratio $r = 1$ are plotted in two-dimensional space of λ and θ in Figure 3-2. Since all these ratios increase with λ, for the region above each line, the corresponding profits is larger than the consumer surplus. From this, the whole space can be divided into five regions. The properties of each region are explained below.

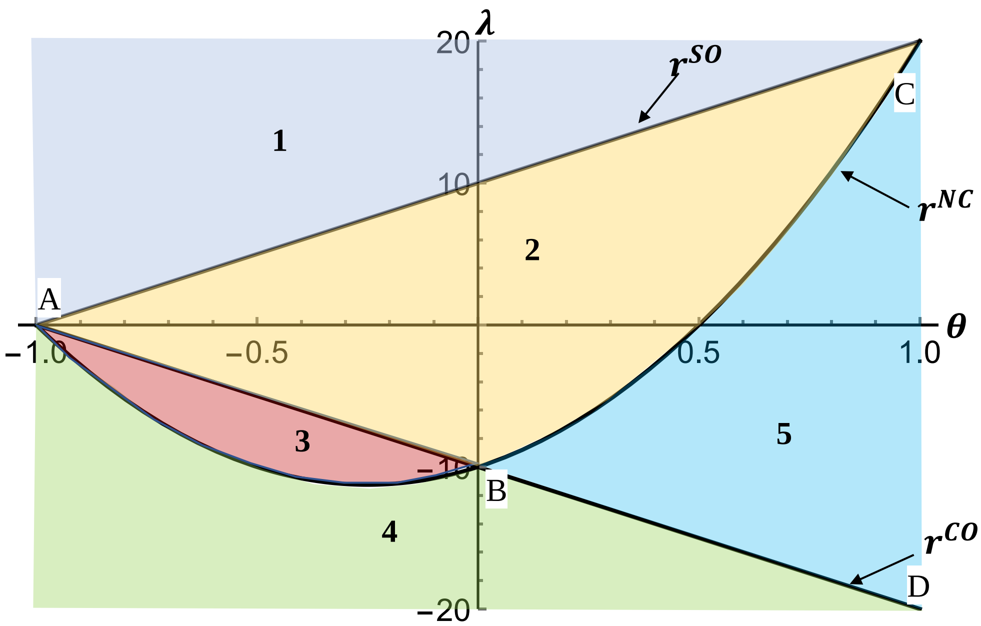


Figure 3-2 Change of Π/CS with respect to λ and θ

Region 1. The total profit of the two ports is higher than consumer surplus for all the cases.

Region 2. Port profit is higher than consumer surplus in NC and CO, and consumer surplus is higher in SO.

Region 3. The total profit is lower than consumer surplus in CO and SO, higher in NC.

Region 4. The total profit is always lower than consumer surplus.

Region 5. Total profit is higher only in CO. In both NC and SO, the consumer surplus is higher.

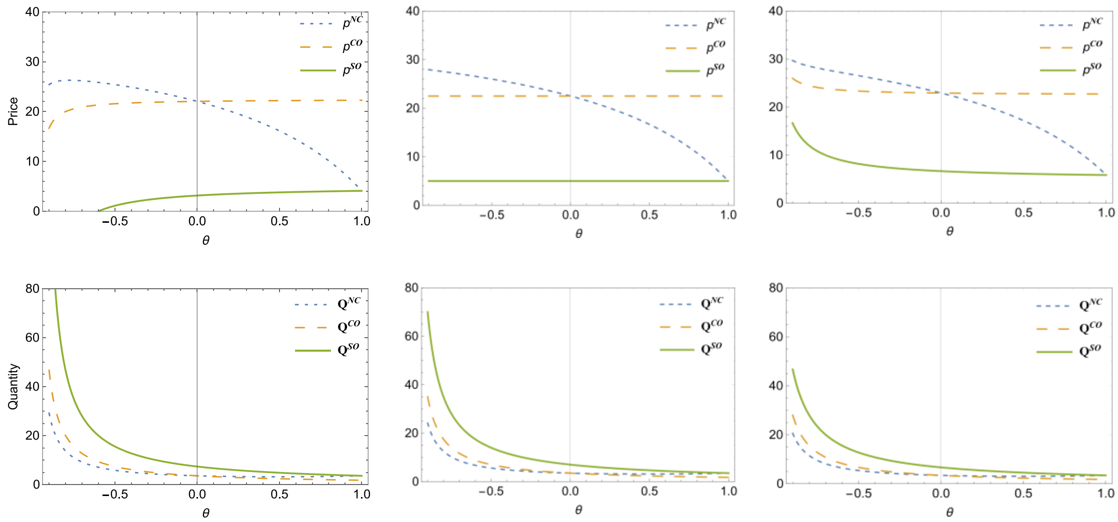
When the services provided by two ports are close complements ($\theta \rightarrow -1$), all three lines intersects with each other, indicating the benefit allocation are the same for all three cases. When they are not related ($\theta = 0$, at point B), CO and NC result in equal distribution of benefits. For almost perfect substitute ($\theta \rightarrow 1$, at point C), NC and SO will result the equal benefit allocation.

From this figure, it can be concluded that the consumer surplus is larger than the port profit in the region below the r^{CO} line when $\theta < 0$ and that below r^{NC} curve when $\theta > 0$. Therefore, when $\theta < 0$, CO is preferred by both the port operator and the society, and consumer surplus can higher than port profit only when there is overcapacity. When $\theta > 0$, competition should be promoted from the social perspective. The consumer surplus can be higher than port profits when $\lambda \leq -\mu(1 - 2\theta)$. Therefore, if the similarity is high enough, shippers can benefit more from the competition, and port operators may have the incentive to cooperate. In this case, government policies are required to promote competition for maximum social benefit, and to promote port expansion.

3.5.3 Change of equilibrium value w.r.t θ

Starting from the distribution of consumer surplus and port profits in Figure 3-2, the price, total throughput, total profit, consumer surplus and social welfare under different combination of λ and θ are compared through numerical simulation.

In Figure 3-3 and Figure 3-4, the change of equilibrium results with θ in the range of (-1, 1) and λ takes the value of -0.5, 0, and 0.5 representing the case of overcapacity, constant unit cost and congestion, respectively.

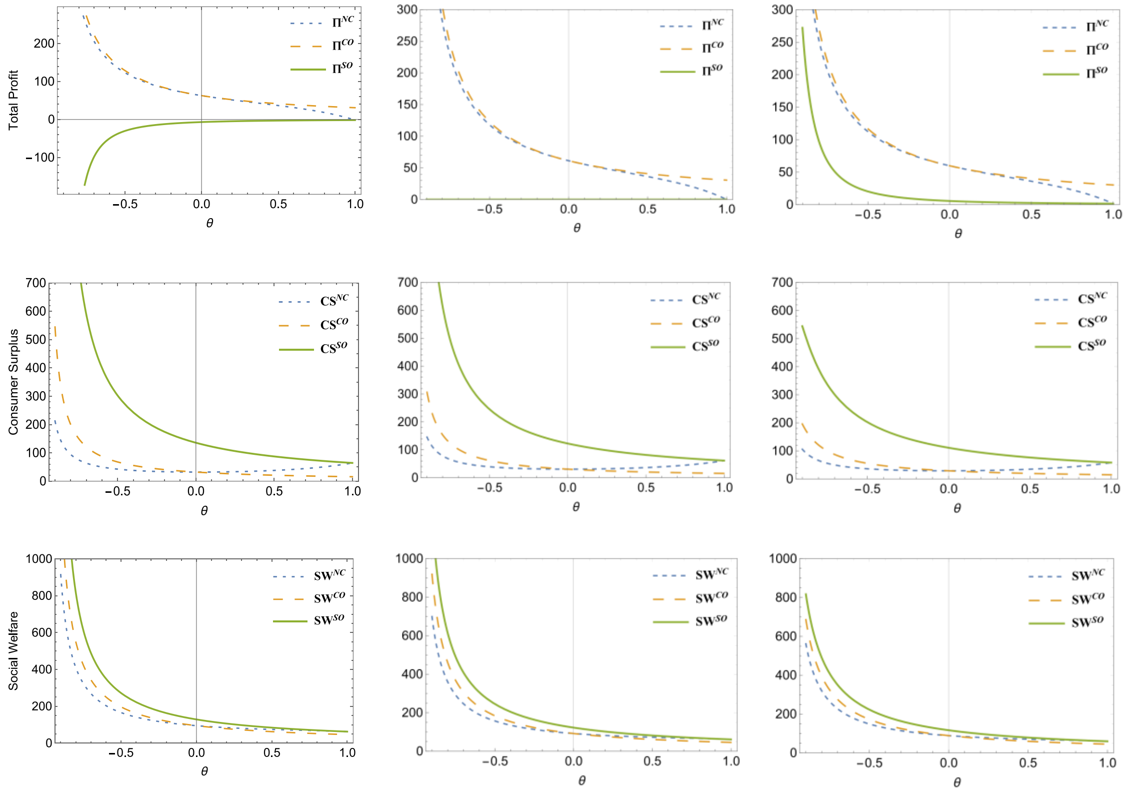


λ=-0.5 λ=0 λ=0.5

Figure 3-3 The impacts of θ on price and total throughput

Figure 3-3 shows that the trends of price and total quantity are consistent with the theoretical results. SO always has the lowest price and highest total throughput. When the two ports are complements ($\theta < 0$), the price in NC is always higher and the total throughput is lower than that in CO. When they are independent ($\theta = 0$), the price in CO and NC are the same. When they are substitutes ($0 < \theta$), the price in NC is lower and throughput is higher than that in CO. However, it should be noted that these strategies generate similarly low throughput when the substitutability is very high. When they are perfect substitute ($\theta \cong 1$), the prices in NC and SO can be very close, which are much lower than that in CO. When $\lambda < 0$, i.e., the ports have overcapacity, the price can increase in CO and SO. When $\lambda > 0$, i.e., when there is congestion, the increasing substitutability will decrease the price in all the three cases, most obviously in NC. When $\lambda = 0$, the price equal to marginal cost in SO.

The increases in θ always reduce the total throughput in CO and SO. For NC, if the two ports are substitutes ($\theta > 0$), higher similarity may increase the total output. In addition, we found when the two ports are complements, the gaps of total throughput among the three cases are very large, while in substitutes, the gap is very small. Therefore, if the two ports are complements, CO is a better strategy as it generates lower prices and higher throughputs. If the two ports are substitutes, NC always offers a lower price compared with CO. For perfect substitutes, NC can offer the same price as the SO.



λ=-0.5 λ=0 λ=0.5

Figure 3-4 The impacts of θ on total profit, consumer surplus and social welfare

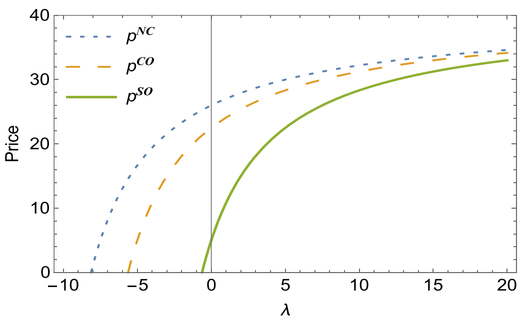
Figure 3-4 illustrates the change of total profit, consumer surplus and social welfare under different combination of λ and θ. The total profit in SO can be negative or zero when $\lambda \leq 0$. As the objective is to maximize social welfare and consumer surplus is big, it is possible to have negative profit. In addition, the increase in θ always reduces the consumer surplus and social welfare for the three cases except in NC. For NC, a larger θ can increase the consumer surplus if $\theta > 0$.

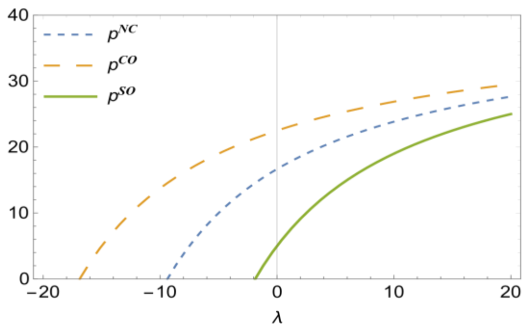
CO is the best strategy for port business as it always provides the highest total profit, but it can reduce shippers' benefit when the substitutability is high. Although SO always provides the highest consumer surplus and social welfare, the profit can be negative in overcapacity. When the two ports are substitutes, NC provides higher consumer surplus and social welfare than CO. When they are complements, the results are always the opposite.

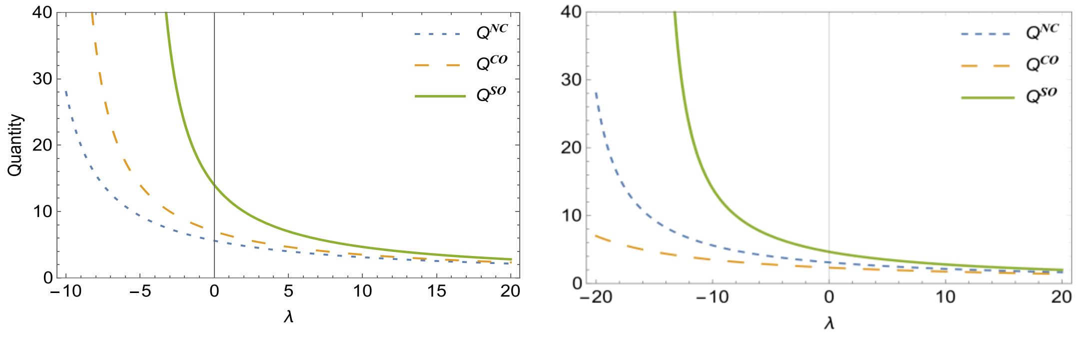
Therefore, NC is not always the best strategy for consumers for different port service relationships. Only when the two ports are substitutes, NC can bring in competition and benefit the shippers more than CO. If the two ports are complements, CO is better than NC for both port profit and shippers' benefit. This is consistent with the results shown in Table 3.

3.5.4 Change of equilibrium value w.r.t. λ

Figure 3-5 to Figure 3-6 present the change of equilibrium results with the change of λ, for θ at -0.5 and 0.5, respectively.



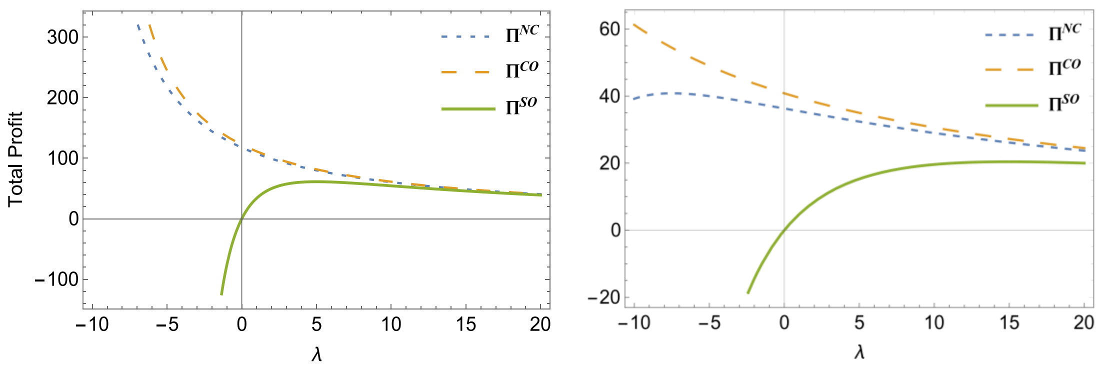


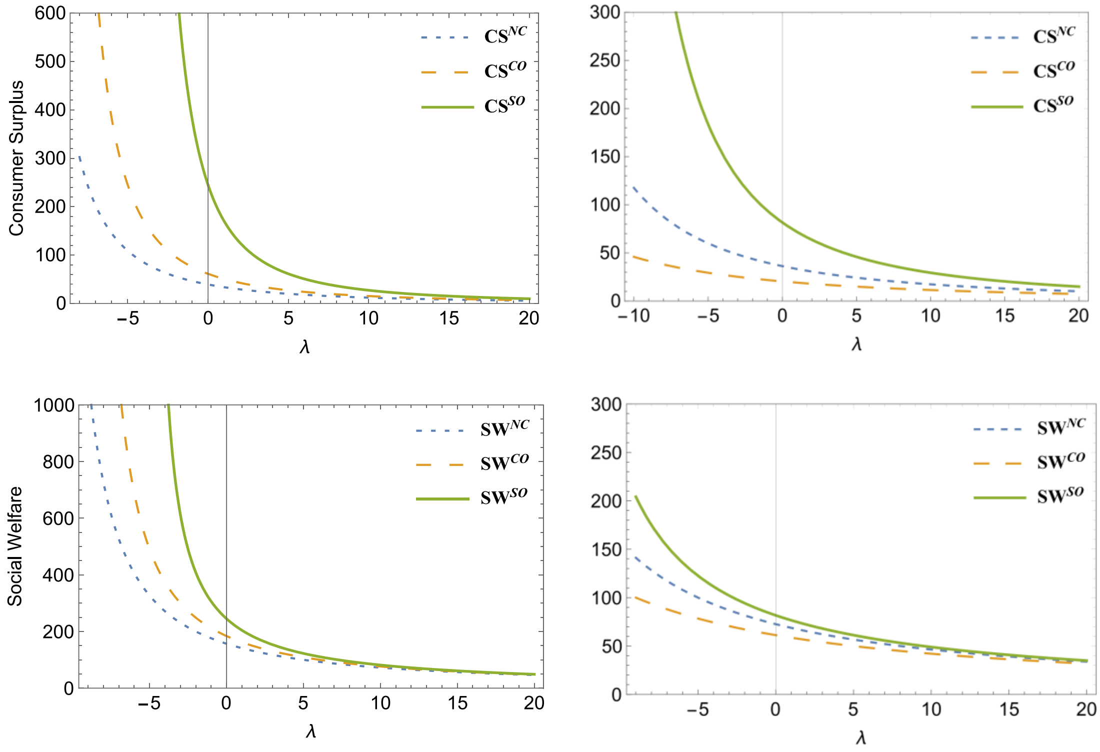


θ =-0.5 θ =0.5

Figure 3-5 The impacts of λ on equilibrium price and total throughput

As shown in Figure 3-5, a large λ always increases the price and decreases the total throughput in all the three strategies. Comparing the overcapacity ($\lambda < 0$) with congestion ($\lambda > 0$), the former always generates a large gap in the price and total throughput among NC, CO, and SO. The higher the overcapacity (a large $|\lambda|$), the larger the gap. When there is congestion ($\lambda > 0$), the gap becomes very small. When the degree of congestion is very high (a large λ), the price and total throughput under the three strategies are almost the same. Thus, if the ports have a large potential for overcapacity, which strategy to adopt can have a large impact on port price and total throughput.





θ =-0.5 θ =0.5

Figure 3-6 The impacts of λ on total profit, consumer surplus and social welfare

Figure 3-6 provides the simulation results for equilibrium profit, consumer surplus and social welfare with the change of λ, and the value of θ at -0.5 and 0.5. The consumer surplus and social welfare always decrease with λ. When the two ports cooperate, the total profit always decreases with λ. For NC, the total profit can increase in overcapacity, depending on the value of λ. If the potential for overcapacity is very large, i.e., $\lambda < 0$ and large $|\lambda|$, the total profit of two ports can increase. This indicates the demand of the two ports is too low compared with its capacity. Therefore, increase demand would result in huge cost reduction and increase profit.

In addition, when the overcapacity exists, the total profit in SO is always negative due to the higher consumer surplus for shippers. The higher degree of overcapacity, the larger the gap for the simulation results among the three strategies. When there is congestion, the gaps are very small, especially when the degree of congestion effect is very high.

Therefore, when overcapacity exists, which strategy taken has great impact on ports and shippers, as well as on the international trade. Although SO is always the best strategy from social perspective, private ports may need government subsidy as it can generate negative profit. The selection of NC or CO depends on the relationship between the ports. When congestion exists, the simulation results for the three cases are very close, especially when the congestion is very high ($10 < \lambda < 20$), the results are nearly the same and much lower than those in overcapacity.

3.6 Discussions and policy implications

Having presented the analytical modeling and simulation results, to highlight the implication of this research on port policy, this section provides a summary on the discussion and some policy implications as below.

First, a government policy should be aimed at maximizing social welfare, while ports are operated by individual businesses. Therefore, although SO naturally generates lowest price and total profit, highest total throughput, consumer surplus and social welfare, it is not attainable if the decision-makers are port managers. Considering that China is still following the market-oriented system, and the port are operated as a private business, SO can only be looked upon as an ideal case. Therefore, it is used as benchmark to judge which strategy (CO or NC) is a better strategy from social perspectives.

Second, ports in a region can be complements, substitutes, or have no relations, which are modeled using parameter θ. When the two ports are complements ($\theta < 0$), CO is better than NC in that it can provide a lower price, higher total throughput, consumer surplus and social welfare. When they are substitutes ($\theta > 0$), NC is better than CO due to its lower price, higher total throughput, consumer surplus and social welfare. From the perspective of port business, CO is always preferred, as it can generate maximum total profit. Therefore, for the government policy to improve social welfare, NC should be encouraged when two ports provide substitutable services, rather than cooperation.

Third, the motivation for the government to initiate port integration policy comes from the concerns of port operators on the fierce competition when there is overcapacity. The result shows when overcapacity exists, port strategies (CO or NC) can have a large impact on ports and shippers, especially the latter when ports are substitutes. Therefore, port integration policies that encourage port cooperation in this case can have detrimental impacts on the shippers.

Forth, reducing the value of the cost factor λ, which is associated with port capacity, can reduce the price, increase the throughput, consumer surplus and social welfare. It can also increase the port profit in CO, but not in NC. In addition, considering the benefit allocation between shippers and port business, when two ports are complements, port business always has higher profits than the consumer surplus in CO if the overcapacity is not so big. When two port are substitutes, port benefits can be lower than the shippers', especially when the substitutability and congestion level are high. Therefore, government policy should consider reducing port congestion and avoid overcapacity, as it can benefit shippers and the society.

Our study can be useful for both public policies and private port operators in port management. For government policies regarding port competition or cooperation, it is not only necessary to consider users' preference on the services provided by the involved ports, but also the current operation status of the ports. For private port business, cooperation is always preferred. However, when two ports are substitutes, cooperation may result in monopoly, which can easily become a public concern. In addition, it is also important to balance the benefits to the shippers and port operators. The benefit allocation is determined jointly by shippers' preference and port operation status. Any changes in these directions would upset the balance between the two sides, and result in the fluctuation in port-shipping market.

3.7 Chapter summary

In the context of port integration in China, this study investigates the best port management strategies (CO or NC) from the perspective of ports, shippers as well as society, under different combination of port attribute and shippers' preference, including whether there exists overcapacity or congestion and whether the relationship of the ports are complements or substitutes. The equilibrium results (including price, total quantity, total profit, consumer surplus and social welfare) of CO, NC and SO are derived and analyzed with respective to port attribute/shippers' preference are carried out, together with the analysis of the benefit allocation between shippers and ports. SO is used as a benchmark to compare the result in CO and NC. A numerical simulation is carried out to illustrate the results.

The major conclusions in this chapter are as follows. From the port operators' perspective, ports always prefer CO as it can generate maximum total profit. This is consistent with the social object when the port services are complements. However, NC is better from social perspective when they are substitutes, as CO can lead to monopoly and social welfare losses, and such losses increases with the level of overcapacity. Hence, government policy should promote NC, rather than CO, when two ports are substitutes. Considering the benefit allocation between ports and shippers, government should aim at reducing congestion and avoid overcapacity, rather than encourage cooperation. Maintaining a right capacity level can help to balance the benefits among shippers and port operators.

Chapter 4 Feasibility of predatory pricing in port competition

According to the analysis in Chapter 3, we have found that the motivation for the government to initiate port integration policy comes from the concerns of port operators on the fierce competition when there is overcapacity. When two ports in the market are highly substitute, it can easily intensify cut-throat competition among ports in the same region. To attract consumers and limited cargos, some ports may take predatory pricing strategy to expand their market share. Predatory pricing is the strategy of using below-cost pricing to undercut competitors and establish a market advantage. In this chapter, a theoretical model is constructed based on Bertrand game to analyze how one port uses predatory pricing to drive its competitor out of the market, to examine whether predatory pricing is feasible in the shipping market. To enable comparison, a benchmark scenario is provided where each port pursues maximum profit by its optimal price in a duopoly game. The feasibility of predatory pricing strategy is studied in a two-stage game. In the first stage, the port with high loyalty customer (or larger market share, called dominating port here-after) adopts predatory price strategy to drive the port with less market share out of the market. In the second stage, when the dominating port gained monopoly power, it will decide the optimal prices to maximize the total profits in both regions. Theoretical analysis is presented and numerical simulation is conducted to examine the impacts of the substitutability and overcapacity on the equilibrium results, and whether the port is profitable consider the two stage as a whole. This study can provide useful suggestions for regional port management and help public policy decision regarding port management.

4.1 Introduction

In the past decades, the shipping market has experienced tremendous changes with the transformation of the global economy and the development of maritime transportation. At the same time, ports also face a rapid changing environment. Due to the overall slowdown of global economic growth and the decline in foreign trade, there is an imbalance between transportation demand and port supply, resulting in a serious problem of port overcapacity and enormous survival pressure for port enterprises. In order to attract cargo flows and maintain market share, ports have to adopt various ways to adapt to the changing environment, to improve the competitiveness of the ports. However, problems such as duplication and homogenization of port competition, waste of shoreline resources, unclear functional divisions, and other factors such as global customer demand and complex logistics systems have intensified competition among ports (Notteboom and Yang, 2017).

Most of the existing ports are survived from a long history of competition (Luo and Grigalunas, 2003; McCalla, 1999). In today's complex market environment, companies with stronger competitiveness, such as better geographical location, more perfect infrastructure, more favorable hinterland cargo sources and more mature service and information technology, can have high probability to out-perform the others in the competition. The ports, as the key nodes in the international trade network, always compete actively when they provide services for the overlap-hinterland. For example, Antwerp, Rotterdam, Bremen and Hamburg in West Europe (Veldman and Bückmann, 2003); Singapore and Tanjung Pelepas in Southeast Asia (Tongzon, 2007); Hong Kong and Shenzhen (Song, 2002; Wang et al., 2012; Wang and Liang, 2022) in South China. In China, although there're seven container ports ranking in the top ten in the world in terms of total container throughput these years, many port cities still attempt to enhance competitiveness by increasing more shipping market share and shoreline resources.

Economic theory suggests that when a monopolistic enterprise faces new market entrants, it tends to adopt a preemptive pricing strategy to protect its dominant market position and deter new competitors (Spence, 1977; Eaton and Lipsey, 1979; Wilson, 1992). Similarity, to obtain more customers and maintain market share, adopting predatory pricing strategy is a common tactic used by ports to respond to current market competition. *Ministry of Transport of the People's Republic of China*[3] in 2006 reported that the price-undercutting among ports not only harms the interests of port enterprises but also affects the development of ports. It is disrespectful to the port workers and is not conducive to the development of the port industry. In the long run, price-undercutting cannot increase the total amount of cargo sources, but can only lead to a decline in corporate profitability, thus affecting the sustainable development of ports. They even proposed four measures to prevent port competition.

However, since the reform and opening up, Chinese economy has experienced a period of rapid development due to the market economic system, where free competition is the key to maximum economic efficiency. It can be said that without market economic system, China would not have such great achievements today, especially that after joining the WTO. From the perspective of individual port, price-undercutting can help to attract more cargo than the competitors, offer shippers a wider range of choices, and allow large shipping corporations to negotiate service agreements with ports. Therefore, in this research, we study the worst case of "price-undercutting", the predatory price in port competition, and try to clarify following questions: (1) How does predatory price strategy arise in port market? (2) In economic theory, the purpose of predatory price is to drive competitors in the same region out of market, so as to obtain a monopoly power. Then, what is the price a port can use to effectively drive its competitor out of market? (3) When the dominant port drives its competitor out of the market, and obtain the monopoly power, can the monopoly profit be higher enough to offset the losses when it uses the

[3] http://www.gov.cn/gzdt/2006-10/12/content_411318.htm

predatory price? In brief, this study attempted to analyze whether predatory price strategy can achieve the result of predatory pricing, is it necessary for government to take measures to ban such competition in the port market. The research results could provide useful suggestions for regional port management and help public policies regarding port management.

Having considered the above research questions, this study designs an analytical model based on Bertrand competition to examine the pricing decision for a port to gain monopoly power from duopoly. Specially, we consider a duopoly market where ports have different competitive condition. The services provided by the two ports are not perfect substitutes, and there exists overcapacity. A benchmark scenario is provided where the two ports compete in Bertrand fashion. The Nash equilibrium prices, throughputs and profits are derived. The feasibility of predatory pricing is studied in two stages. In the first stage, the dominating port with a larger market share adopts predatory pricing by decreasing prices enough to drive the competitor out of the market. In the second stage, the monopoly operates both ports, and determines the optimal prices at two sites to maximize total profits. Finally, theoretical analysis is presented and numerical simulation is conducted to examine the impacts of the substitutability and overcapacity on the results.

The remainder of this study is organized as follows. In Section 4.2, we present a literature review of relevant studies. In Section 4.3, we design the game model based on Bertrand competition considering duopoly stage and monopoly stage respectively. Section 4.4 gives a comparative analysis of the equilibrium results. Numerical examples and impacts of the parameters are presented in Section 4.5. Section 4.6 provides a discussion and policy implication for the propositions and numerical simulation results. Summary and conclusions are provided in Section 4.7.

4.2 Literature review

Port competition is a very important research direction in the field of maritime transportation, and a number of studies have been conducted to analyze port competition with game theoretical models (Anderson et al., 2008; Saeed and Larsen, 2010; Luo, Liu and Gao, 2012; Zhuang, Luo and Fu, 2013; Do et al., 2015). Although most of the game theoretical models are based on many assumptions to enable the theoretical analysis, their research findings provided a promising direction for studying the nature of port competition in the maritime industry. For example, Wan, Basso and Zhang (2016) investigated the strategic port investment of collaboration among local governments considering two competing ports and a common inland. The results revealed that there are conflicts of interest between port authorities and inland governments when making joint accessibility investment decisions. Cui and Notteboom (2017) provided a game theory model to analyze the emission control in port areas and port privatization levels considering a private port and a landlord port. The findings indicated that the imposition of emission tax can result in a decrease in port cargo volume, hence damage the profitability of both port operators and shipping companies. Zhang et al. (2018) established a game theoretical model of port competition to address the design and pricing strategy issues in multimodal transportation networks. Dong and Huang (2022) studied the inter-port price competition in a multi-port gateway region (MPGR) with a two-stage game model, the results showed that price matching strategy is still the unique subgame perfect Nash Equilibrium for the two container ports in an MPGR even the two ports have different variable cost.

In maritime economies, price competition is typically used after capacity investment in port studies. The application of Bertrand model is commonly applied to model price competition. For example, Demichelis and Tarola (2006) analyzed capacity expansion and dynamic monopoly pricing from the perspective of a monopolist. Luo, Liu and Gao (2012) modeled two ports competitive strategies in transition from monopoly to duopoly by pricing competition and capacity investment. Some studies also directly investigated port competition with two stage-game model followed a Bertrand game. Saeed and Larsen (2010) applied a two-stage model to examine the competition among container terminals of one port in Pakistan. Song et al. (2016) investigated the interactions among shipping liners and port authorities from a maritime supply chain by a two-stage game model and Nash equilibrium is derived by solving the Bertrand game. Some directly compared the Cournot and Bertrand competition to examine the port privatization choice by incorporating port competition. Lee, Lim and Choi (2017) examined port privatization under either Bertrand or Cournot competition, and the results revealed that the port ownership may vary depending on the competition mode of the firms. Although these studies for port competition using pricing strategies provide different interesting insights by focusing on specific market conditions and port attributes. However, existing research on port capacity and pricing from duopoly to monopoly is scare.

This study is motivated by the issue of port cutting-throat competition and port integration in China. In the last decade, a new pattern of port integration-"One port One Port Group" policy has been raised in China to reduce excess port competition and avoid port resource misallocation. However, such port integration is likely to lead to regional port monopoly and reduce social welfare (Xing, Liu and Chen, 2018). In addition, pricing strategy is the most commonly used for a port firm as summarized above, and a common view is that port price competition especially price-undercutting competition can have negative effects on the long-term profitability of the port industry, as well as the quality of services offered by ports. Therefore, this paper discusses that what is the concern if price-undercutting is inevitable? In this study, we examined how can one port drive its competitor out of the market using predatory price, and whether it is profitable for one port to drive its competitor out of the market and obtain the monopoly power.

Our model is motivated by Luo, Liu and Gao (2012), which explained the transition of market power from monopoly to duopoly considering pricing and capacity decisions of two ports that have different competitive advantages. They used preemptive pricing to prevent the smaller player from gaining the market share or entering the market. Different to their study, the pricing strategy adopted in our study is predatory price, which is also an important part of game theory. Predatory price is a pricing strategy in which a company sets price very low of its products or services to drive its competitors out of the market and ultimately establish a monopoly (Elzinga and Mills, 2000). The idea is that the company can sustain losses in the short-term in order to gain a dominant market position in the long-term. Price competition is important because it determines the flow of sales and revenue of firms (Ubochioma, 2021). Predatory pricing has been a relatively vague concept in antitrust law. This may be because emotive terms such as predatory pricing do not unite and sometimes defy analysis (Williamson, 1977). According to the strategic theory of predatory pricing, a dominant firm can use its market power to engage in predatory pricing in the short-term, because it can eventually raise prices and recoup its losses once its competitors have been eliminated. Therefore, in our study, we adopted predatory pricing to examine how can one port drive its competitor out of the market and gain monopoly power from duopoly market. Each port is assumed to have different competitive conditions, and there exists overcapacity and substitute between the two ports. The result can help to understand whether it is necessary for government to take measures to prevent price competition in the port market.

4.3 The model

4.3.1 Basic assumption

In this study, what we considered are two competitive ports (defined as Port 1 and Port 2) in a duopoly market and the basic assumptions based on the Bertrand Competition are presented. Specifically, we focus on two ports with different competitive advantages serving the same hinterland market, and the two ports compete through price strategy to maximize profits. The services provided by them are substitutable, but not perfect substitute, and there exists overcapacity.

The decision process includes two stages. In the first stage, the two profit-maximizing ports compete by pricing, while dominating port applies predatory pricing to drive the competitor out of market. In the second stage, the port which obtained the monopoly stage operates the facilities at both facilities, and determines the optimal prices at two sites to maximize total profit.

Firstly, our basic model assumption begins with a liner demand function in the duopoly market.

$$q_1(p_1, p_2) = \alpha_1 \bar{x} - p_1 + \gamma p_2 \quad (4\text{-}1)$$

$$q_2(p_1, p_2) = \alpha_2 \bar{x} - p_2 + \gamma p_1 \quad (4\text{-}2)$$

Where α_1 and α_2 stand for the loyal customer market share of Port 1and Port 2, $\alpha_1 + \alpha_2 = 1$, here $\alpha_1 > \alpha_2$ indicates that Port 1 has larger initial market share than Port 2. $\bar{x}$ represents the overall demand of the two ports, which is determined by the total import and export in the same hinterland. γ stands for the substitute relationship between Port 1 and Port 2, and $0 < \gamma < 1$, which represents the similarity of the two ports. When γ is very small, the service provided by the two ports are very different, hence the substitutability is low. When γ is large, or close to 1, the services provided by the two are similar, hence the substitutability is high. Moreover, p_1 and p_2 represent the prices at each port respectively.

If Port 1 drove Port 2 out of market and obtain the monopoly power, it will provide the service for its own customer, as well as the customers originally serviced by Port 2. Therefore, two demand functions in Equation (4-1, 4-2) still exist, but Port 1 will decide the optimal prices for customers to maximize the profit in both regions.

Secondly, on the cost side, we used a general quadratic cost function as follows,

$$C(q_i) = cq_i - \lambda q_i^2,\ i\epsilon\{1,2\}. \tag{4-3}$$

Where q_i denotes the total cargo handling services provided by port i, λ the cost factor representing overcapacity ($\lambda > 0$), and $c > 0$, representing the marginal cost when $\lambda = 0$. Then we can obtain, $mc(q_i) = c - 2\lambda q_i, mc'(q_i) = -2\lambda$.

The model solution follows the real-world decision-making process. In the first stage, the equilibrium results for the two ports in the duopoly market are determined by Bertrand competition, then the dominating port applies predatory pricing to drive the other one out of the market and identifies the necessary conditions for achieving this. In the second stage, the monopoly port determines the optimal prices in both ports to maximize the total profits. And we explore whether can the monopoly profit be higher enough to offset the profit loss due to the use of predatory price to drive Port 2 out of the market.

4.3.2 Predatory pricing in duopoly stage

In this Section, we use Bertrand Competition to present the theoretical analysis for the duopoly stage. We assume that there're two ports competing for market share using predatory price strategy, and the one with higher loyal customer attempts to reduce price to drive the other port out of the shipping market.

First, each port sets the price independently to maximize its own profit, then the equilibrium price and the decision process can be presented as,

$$\max_{p_i} \Pi_i = p_i q_i - (cq_i - \lambda q_i^2), \text{ for } i \in \{1,2\}. \tag{4-4}$$

The first order conditions (FOCs) are,

$$\frac{\partial \Pi_1}{\partial p_1} = (1 - 2\lambda)\alpha_1 \bar{x} - 2(1 - \lambda)p_1 + \gamma(1 - 2\lambda)p_2 + c = 0, \tag{4-5}$$

$$\frac{\partial \Pi_2}{\partial p_2} = (1-2\lambda)\alpha_2\bar{x} - 2(1-\lambda)p_2 + \gamma(1-2\lambda)p_1 + c = 0.$$

And the Hessian matrix is $\begin{bmatrix} \frac{\partial^2 \Pi_1}{\partial p_1{}^2} & \frac{\partial^2 \Pi_1}{\partial p_1 \partial p_2} \\ \frac{\partial^2 \Pi_2}{\partial p_2 \partial p_1} & \frac{\partial^2 \Pi_2}{\partial p_2{}^2} \end{bmatrix} = \begin{bmatrix} -2(1-\lambda) & \gamma(1-2\lambda) \\ \gamma(1-2\lambda) & -2(1-\lambda) \end{bmatrix}$, to satisfy the objective function, the second order condition and the Hessian matrix should require,

$$-2(1-\lambda) < 0,$$
$$[2(1-\lambda) + \gamma(1-2\lambda)][2(1-\lambda) - \gamma(1-2\lambda)] > 0. \qquad (4\text{-}6)$$

Then it should satisfy $0 < \lambda < 1$, $[2(1-\lambda) + \gamma(1-2\lambda)] > 0$ and $[2(1-\lambda) - \gamma(1-2\lambda)] > 0$.

The best response function of port 1 and port 2,

$$p_1{}^*(p_2) = \frac{(1-2\lambda)\alpha_1\bar{x} + \gamma(1-2\lambda)p_2 + c}{2(1-\lambda)}, \; p_2{}^*(p_1) = \frac{(1-2\lambda)\alpha_2\bar{x} + \gamma(1-2\lambda)p_1 + c}{2(1-\lambda)} \qquad (4\text{-}7)$$

From the first order conditions (FOCs), the optimum equilibrium prices of the two ports can be obtained $(p_1{}^*, p_2{}^*)$:

$$p_1{}^* = \frac{(\mu\alpha_1 + \gamma\sigma\alpha_2)\sigma\bar{x} + (\mu+\gamma\sigma)c}{(\mu+\gamma\sigma)(\mu-\gamma\sigma)}, \; p_2{}^* = \frac{(\mu\alpha_2 + \gamma\sigma\alpha_1)\sigma\bar{x} + (\mu+\gamma\sigma)c}{(\mu+\gamma\sigma)(\mu-\gamma\sigma)} \qquad (4\text{-}8)$$

where $2(1-\lambda) = \mu$, $(1-2\lambda) = \sigma$. $\mu > 0, \mu > \sigma$.

And the equilibrium quantity for each port can be written as $(q_1{}^*, q_2{}^*)$:

$$q_1{}^* = \frac{(\mu\alpha_1 + \gamma\sigma\alpha_2)\bar{x} - (\mu+\gamma\sigma)(1-\gamma)c}{(\mu+\gamma\sigma)(\mu-\gamma\sigma)}, q_2{}^* = \frac{(\mu\alpha_2 + \gamma\sigma\alpha_1)\bar{x} - (\mu+\gamma\sigma)(1-\gamma)c}{(\mu+\gamma\sigma)(\mu-\gamma\sigma)}. \qquad (4\text{-}9)$$

Therefore, the optimal profit in Bertrand competition for Port 1 can be obtained,

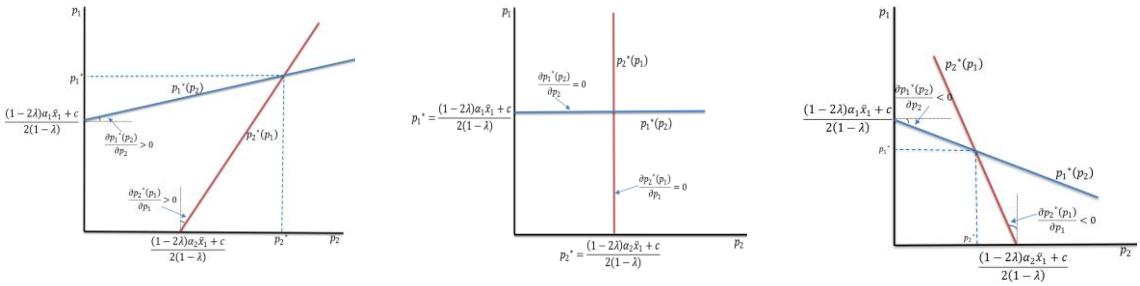
$$\Pi_1{}^* = \frac{\big((\mu\alpha_1 + \gamma\sigma\alpha_2)B\bar{x} + (\mu+\gamma\sigma)c\big)\big((\mu\alpha_1 + \gamma\sigma\alpha_2)\bar{x} - (\mu+\gamma\sigma)(1-\gamma)c\big)}{(\mu+\gamma\sigma)^2(\mu-\gamma\sigma)^2} -$$
$$\frac{c\big((\mu\alpha_1 + \gamma\sigma\alpha_2)\bar{x} - (\mu+\gamma\sigma)(1-\gamma)c\big)(\mu+\gamma\sigma)(\mu-\gamma\sigma)}{(\mu+\gamma\sigma)^2(\mu-\gamma\sigma)^2} + \frac{\lambda\big((\mu\alpha_1 + \gamma\sigma\alpha_2)\bar{x} - (\mu+\gamma\sigma)(1-\gamma)c\big)^2}{(\mu+\gamma\sigma)^2(\mu-\gamma\sigma)^2} \qquad (4\text{-}10)$$

From Eq.(4-6), we can find that the slope of the Best Response Functions (BRFs) for Port 1 can be obtained by differentiating its FOC function w.r.t. p_2,

$$\frac{\partial p_1{}^*}{\partial p_2} = \frac{\gamma(1-2\lambda)}{2-2\lambda} = \begin{cases} > 0, if \;\; 0 < \lambda < \frac{1}{2}\,; \\ = 0, if \;\; \lambda = \frac{1}{2}; \\ < 0, if \;\; \frac{1}{2} < \lambda < 1. \end{cases} \tag{4-11}$$

Here the slope of the BRF satisfies, $\frac{\partial p_2{}^*}{\partial p_1} < \gamma$, where $0 < \gamma < 1$. In addition, we can obtain the same BRFs for Port 2.

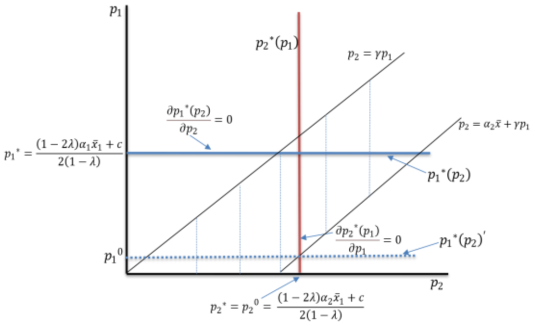
The BRFs of the two ports have negative, zero and positive slopes are shown in Figure 4-1.

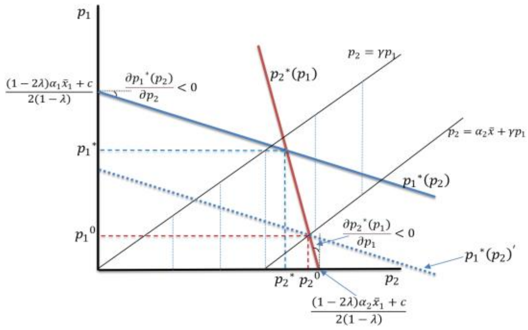


(a) $\frac{\partial p_1{}^*}{\partial p_2} > 0$ and $\frac{\partial p_2{}^*}{\partial p_1} > 0$ (b) $\frac{\partial p_1{}^*}{\partial p_2} = 0$ and $\frac{\partial p_2{}^*}{\partial p_1} = 0$ (c) $\frac{\partial p_1{}^*}{\partial p_2} < 0$ and $\frac{\partial p_2{}^*}{\partial p_1} < 0$

Figure 4-1 BRFs for different $\frac{\partial p_1{}^*}{\partial p_2}$ and $\frac{\partial p_2{}^*}{\partial p_1}$

For Figure 4-1(a), when $0 < \lambda < \frac{1}{2}$, the slopes of the BRFs for both Port 1 and Port 2 are positive, indicating that a decrease in price of Port 1 will stimulate a decrease in price of Port 2's price at the same time. For Figure 4-1(b), when $\lambda = \frac{1}{2}$, the slopes of the BRFs are zero, in this case, when Port 1 reduces its price from the equilibrium price, the price of Port 2 remains unchanged, as $\frac{\partial p_1{}^*}{\partial p_2} = 0$ and $\frac{\partial p_2{}^*}{\partial p_1} = 0$. For Figure 4-1(c), the slopes of both ports BRFs are negative, meaning that for a price reduction in Port 1, Port 2 should increase its price to maximize the profit. From the above discussion, we can find that when $0 < \lambda < \frac{1}{2}$, the slope of marginal cost is negative ($-1 < mc' < 0$). In this case, Port 1 is most likely to drive Port 2 out of the market by predatory price strategy. Further, the cases of part(b) and (c) can be illustrated in Figure 4-2.





(i) $\frac{\partial p_1^*}{\partial p_2} = 0$ and $\frac{\partial p_2^*}{\partial p_1} = 0$ (ii) $\frac{\partial p_1^*}{\partial p_2} < 0$ and $\frac{\partial p_2^*}{\partial p_1} < 0$

Figure 4-2 Port 2 response to port 1's price reduction

As shown in Figure 4-2(i), where both slopes of the BRFs for Port 1 and Port 2 are zero, we observe that when Port 1 reduces its price from optimal price ($p_1{}^*$) to ($p_1{}^0$), the price of Port 2 will have no change because the slope of BRF is zero. In Figure 4-2(ii), where both slopes of the BRFs for Port 1 and Port 2 are negative, when Port 1 drives down its price from the optimal price ($p_1{}^*$) to ($p_1{}^0$), the price of Port 2 increases from the optimal price ($p_2{}^*$) to ($p_2{}^0$), rather than decreases. For these two scenarios, the price and profit of Port 1 may have reduced to negative when Port 1 drives Port 2 out of the market, and there is no incentive for Port 1 to reduce its price to drive Port 2 out of the market.

Therefore, only in Figure 4-1(a), when both slopes of the BRFs for Port 1 and Port 2 are positive ($0 < \lambda < \frac{1}{2}$), for a price reduction in Port 1, Port 2 also needs to offset its price to maximize the profit. In this scenario, when the slopes of the BRFs for both ports are positive, Port 1 has the ability to drive Port 2 out of the market.

In this part, Port 1 decreases its price from the optimal price ($p_1{}^*$), and attempts to use predatory price strategy to drive Port 2 out of the market. When the demand of Port 2 all transferred to Port 1, then it satisfies the condition that Port 1 drives Port 2 out of the market. As shown in Figure 4-1(a), when $0 < \lambda < \frac{1}{2}$, we sets a predatory price $(p_1{}^0)$ lower than the equilibrium price $(p_1{}^*)$ for Port 1, Port 2 also has a price $(p_2{}^0)$, which is lower than the equilibrium price $(p_2{}^*)$. If $p_1{}^0$ is a sufficiently low that makes $q_2 = 0$, then it is credible that the predatory pricing is an effective strategy.

First, we rewrite the demand function of Port 2,

$$p_2 = \alpha_2\bar{x} - q_2 + \gamma p_1 \tag{4-12}$$

From this equation, we can find how port 2's shipping demand changed for different prices charged at the two ports.

$$\begin{cases} q_2 = 0, & if\ \ p_2 \geq \alpha_2\bar{x} + \gamma p_1 \\ 0 < q_2 \leq \alpha_2\bar{x}, & if\ \alpha_2\bar{x} + \gamma p_1 > p_2 \geq \gamma p_1 \\ q_2 > \alpha_2\bar{x}, & if\ \ p_2 < \gamma p_1 \end{cases} \tag{4-13}$$

Equation (4-13) segments the demand region for Port 2 into three parts as shown in Figure 4-3. Where below line BE, the demand of port 2 is zero ($q_2 = 0$), this is also the region where Port 1 can drive Port 2 out of the market. Between line BE and line OF, the demand for Port 2 will increase and less than the initial market demand ($\alpha_2\bar{x}$), but above line OF, the demand for Port 2 will larger than the initial market ($\alpha_2\bar{x}$). In addition, by modifying Equation(4-13), we obtain the equation for line OF $p_2 = \gamma p_1$ and line BE $p_2 = \alpha_2\bar{x} + \gamma p_1$ as shown in Figure 4-3, it also includes the BRF with a positive slope and demand segmentation, corresponding to Figure 4-1(a).

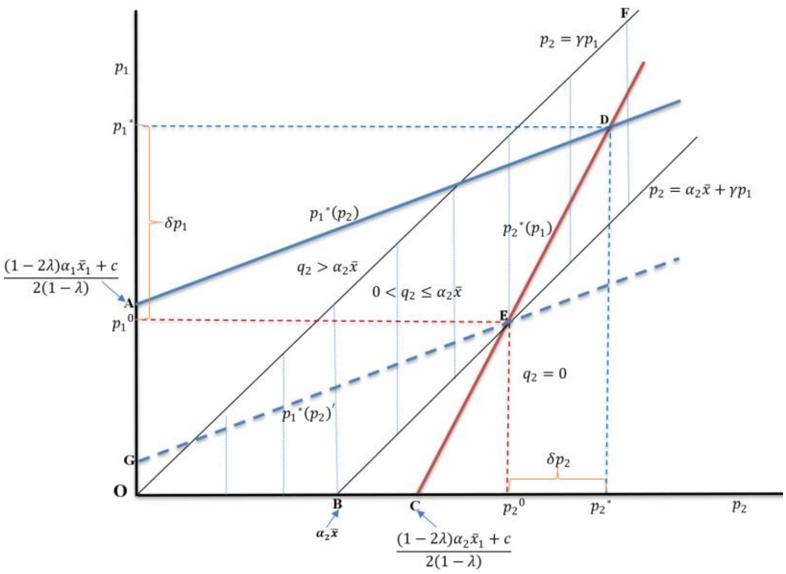


Figure 4-3 Demand for port 2 and BRF

Having explored the equilibrium price in duopoly competition, we found when $\frac{\partial p_1^*}{\partial p_2} > 0$ and $\frac{\partial p_2^*}{\partial p_1} > 0$, i.e., $0 < \lambda < \frac{1}{2}$, Port 1 is most likely to drive Port 2 out of the market by predatory price strategy as shown in Figure 4-3. Moreover, as $\frac{\partial p_2^*}{\partial p_1} = \frac{\gamma(1-2\lambda)}{2(1-\lambda)} < \gamma$, the slope of line CD is small than that of line BE. This is the condition for Port 1 to be able to drive Port 2 out of the shadow area, as shown in Figure 4-3. When the price of Port 1 is reduced to $p_1{}^0$, the demand for Port 2 is reduced to zero, then the predatory price by Port 1 can be an effective strategy to drive Port 2 out of the market. As shown in Figure 4-3, combined line CD and line BE,

$$p_2^*(p_1) = \frac{(1-2\lambda)\alpha_2\bar{x} + \gamma(1-2\lambda)p_1 + c}{2(1-\lambda)},$$
$$p_2 = \alpha_2\bar{x} + \gamma p_1. \qquad (4\text{-}14)$$

we can obtain the condition for an effective predatory price of port 1 drive port 2 out of the market $(p_1{}^0, p_2{}^0)$,

$$p_1{}^0 = \frac{c-\alpha_2\bar{x}}{\gamma},\ p_2{}^0 = c. \qquad (4\text{-}15)$$

Here when the price of Port 1 decreases to $\frac{c-\alpha_2\bar{x}}{\gamma}$, the price of Port 2 will equal to the average marginal cost (c). And it is necessary to satisfy $c > \alpha_2 \bar{x}$ to ensure ${p_1}^0 > 0$. Under this condition, the quantity for each port,

$$ {q_1}^0 = \frac{(\gamma\alpha_1 + \alpha_2)\bar{x} - (1-\gamma^2)c}{\gamma}, \ {q_2}^0 = 0 \qquad (4\text{-}16) $$

Therefore, the profit for Port 1 in this condition can be obtained,

$$ {\Pi_1}^0 = \frac{(c-\alpha_2\bar{x})\big((\gamma\alpha_1+\alpha_2)\bar{x}-(1-\gamma^2)c\big) - c\gamma\big((\gamma\alpha_1+\alpha_2)\bar{x}-(1-\gamma^2)c\big) + ((\gamma\alpha_1+\alpha_2)\bar{x}-(1-\gamma^2)c^2)}{\gamma^2} \qquad (4\text{-}17) $$

4.3.3 Equilibrium in monopoly stage

In this stage, we assume that Port 2 has been driven out of the market, and Port 1 has obtained a monopoly power. Then Port 1 will operate the facilities for its own customer, as well as the customers originally serviced by Port 2. Port 1 will adjust the prices at both ports to maximize the total profit. Then in monopoly stage, the decision process can be presented as,

$$ \max_{(p_1,\, p_2)} (\Pi_1 + \Pi_2) = p_1 q_1 - (c q_1 - \lambda {q_1}^2) + p_2 q_2 - (c q_2 - \lambda {q_2}^2) \qquad (4\text{-}18) $$

Maximize the total profit with respect to p_1 and p_2. The FOC conditions (FOCs) can be obtained,

$$ \begin{aligned} \frac{\partial(\Pi_1+\Pi_2)}{\partial p_1} &= [(1-2\lambda)\alpha_1 + 2\lambda\gamma\alpha_2]\bar{x} + c(1-\gamma) + 2[\gamma - \lambda(1+\gamma)]p_2 - \\ &\quad 2[1-\lambda(1+\gamma)]p_1 = 0\,, \\ \frac{\partial(\Pi_1+\Pi_2)}{\partial p_2} &= [(1-2\lambda)\alpha_2 + 2\lambda\gamma\alpha_1]\bar{x} + c(1-\gamma) + 2[\gamma - \lambda(1+\gamma)]p_1 - \\ &\quad 2[1-\lambda(1+\gamma)]p_2 = 0\,. \end{aligned} \qquad (4\text{-}19) $$

And the Hessian Matrix is,

$$ \begin{bmatrix} \frac{\partial^2(\Pi_1+\Pi_2)}{\partial {p_1}^2} & \frac{\partial^2(\Pi_1+\Pi_2)}{\partial p_1 \partial p_2} \\ \frac{\partial^2(\Pi_1+\Pi_2)}{\partial p_2 \partial p_1} & \frac{\partial^2(\Pi_1+\Pi_2)}{\partial {p_2}^2} \end{bmatrix} = \begin{bmatrix} -2[1-\lambda(1+\gamma)] & 2[\gamma-\lambda(1+\gamma)] \\ 2[\gamma-\lambda(1+\gamma)] & -2[1-\lambda(1+\gamma)] \end{bmatrix}. $$

To ensure the total profit maximization, the second order condition (SOC) and the Hessian matrix require,

$$-2[1-\lambda(1+\gamma)] < 0,$$
$$4[1-\lambda(1+\gamma)]^2 - 4[\gamma-\lambda(1+\gamma)]^2 > 0. \qquad (4\text{-}20)$$

Therefore, it should satisfy $1-\lambda(1+\gamma) > 0$, i.e., $\lambda < \frac{1}{(1+\gamma)}$. And $[1-\lambda(1+\gamma)+\gamma-\lambda(1+\gamma)](1-\gamma) > 0$, since $0 < \gamma < 1$, it requires $(1-2\lambda)(1+\gamma) > 0$, i.e., $\lambda < \frac{1}{2}$.

From the first order conditions (FOCs), the optimum equilibrium prices determined by Port 1 can be obtained $({p_1}^m, {p_2}^m)$:

$${p_1}^m = \frac{[2\rho(2\lambda\gamma\alpha_2+\sigma\alpha_1)+2\varphi(\sigma\alpha_2+2\lambda\gamma\alpha_1)]\bar{x}+2(\rho+\varphi)c(1-\gamma)}{4(\rho^2-\varphi^2)},$$
$${p_2}^m = \frac{[2\rho(2\lambda\gamma\alpha_1+\sigma\alpha_2)+2\varphi(\sigma\alpha_1+2\lambda\gamma\alpha_2)]\bar{x}+2(\rho+\varphi)c(1-\gamma)}{4(\rho^2-\varphi^2)}. \qquad (4\text{-}21)$$

Where $(1-2\lambda) = \sigma$, $[1-\lambda(1+\gamma)] = \rho$, $[\gamma-\lambda(1+\gamma)] = \varphi$, $(\rho^2-\varphi^2) = (1-2\lambda)(1-\gamma^2) > 0$. And the optimal throughput for Port 1 at two sites can be $({q_1}^m, {q_2}^m)$:

$${q_1}^m = \frac{4(\rho^2-\varphi^2)\alpha_1\bar{x}+(4\rho\lambda\gamma-2\rho\sigma)(\alpha_1\bar{x}-\alpha_2\bar{x})+2\varphi\sigma(\gamma\alpha_1\bar{x}-\alpha_2\bar{x})-4\varphi\lambda\gamma(\alpha_1\bar{x}-\gamma\alpha_2\bar{x})-2(1-\gamma)(\rho+\varphi)c(1-\gamma)}{4(\rho^2-\varphi^2)},$$
$${q_2}^m = \frac{4(\rho^2-\varphi^2)\alpha_2\bar{x}+(4\rho\lambda\gamma-2\rho\sigma)(\alpha_2\bar{x}-\alpha_1\bar{x})+2\varphi\sigma(\gamma\alpha_2\bar{x}-\alpha_1\bar{x})-4\varphi\lambda\gamma(\alpha_2\bar{x}-\gamma\alpha_1\bar{x})-2(1-\gamma)(\rho+\varphi)c(1-\gamma)}{4(\rho^2-\varphi^2)}. \qquad (4\text{-}22)$$

Therefore, the total throughput in monopoly stage is $q_m = {q_1}^m + {q_2}^m$. And the optimal profit in monopoly stage is $\Pi_m = {p_1}^m{q_1}^m - \left(c{q_1}^m - \lambda {q_1}^{m2}\right) + {p_2}^m{q_2}^m - \left(c{q_2}^m - \lambda {q_2}^{m2}\right)$

4.4 Theoretical analysis among the two stages

In this Section, we give a comparison of the equilibrium results between the duopoly and monopoly stage to determine the condition for Port 1 to drive Port 2 out of the market, and whether Port 1 can make a profit when it obtains a monopoly in the market. We first state propositions and conclusions of the comparison, then provide the proof for these results.

Proposition 1. ${p_1}^* > {p_2}^*$, if $\alpha_1 > \alpha_2$; $\delta p_1 > \delta p_2$, where $\delta p_1 = {p_1}^* - {p_1}^0$, $\delta p_2 = {p_2}^* - {p_2}^0$.

Proposition1 reveals that in a duopoly market, when the market share of Port 1 is larger than that of Port 2, the equilibrium price of Port 1 is always higher than that of Port 2. Furthermore, Port 1 should always reduce more price than Port 2 to drive Port 2 out of the shipping market. This conclusion can be proven by comparing the equilibrium prices in the duopoly market.

$$ {p_1}^* - {p_2}^* = \frac{(\alpha_1 - \alpha_2)\sigma\bar{x}}{[2(1-\lambda)+(1-2\lambda)\gamma]} > 0 \text{ when } \alpha_1 > \alpha_2. \quad (4\text{-}23) $$

In addition, the proof of the price reduction ($\delta p_1 > \delta p_2$) is as follows. According to Figure 4-3, the slope of the best response function (line CD) of Port 2 is $\frac{\partial {p_2}^*}{\partial p_1} = \frac{\gamma(1-2\lambda)}{2(1-\lambda)}$, and the slope of the market demand segmentation line (line BE) of Port 2 is γ. Here, $\frac{\gamma(1-2\lambda)}{2(1-\lambda)} < \gamma < 1$ when $0 < \lambda < \frac{1}{2}$, which is a necessary condition for Port 1 to drive Port 2 of the market. Therefore, $\frac{\partial {p_2}^*}{\partial p_1} < 1$, then $\frac{\delta p_1}{\delta p_2} > 1$, $\delta p_1 > \delta p_2$. It reveals that when the prices of Port 1 and Port 2 are reduced to ${p_1}^0$ and ${p_2}^0$ respectively, the price reduction of Port 1 is always greater than that of Port 2.

Proposition 2. ${p_1}^0 > {p_2}^0$ if $c > \frac{\alpha_2\bar{x}}{1-\gamma}$; ${p_1}^0 < {p_2}^0$ if $c < \frac{\alpha_2\bar{x}}{1-\gamma}$.

Proposition 2 reveals that when Port 1 drives Port 2 out of the market, the price of Port 2 is always reduced to the average marginal cost (c). While the price of Port 1 may be higher or lower than c, depending on the comparison of average marginal cost and Port 2's weighted loyal customers.

$$ {p_1}^0 - {p_2}^0 = \frac{(1-\gamma)c - \alpha_2\bar{x}}{\gamma} >/=/< 0, \text{ if } c >/=/< \frac{\alpha_2\bar{x}}{1-\gamma}. \quad (4\text{-}24) $$

Therefore, from proposition1 and proposition2, we can conclude that when Port 1 can drive Port 2 out of the market, the price reduction of Port 1 is always greater than that of Port 2. However, the price of Port 1 maybe higher or lower than that of Port 2 depending on the comparison of the average marginal cost (c) and the initial market share of Port 2.

Proposition 3. ${p_i}^m > {p_i}^*$, if $0 < \lambda < \frac{1}{2}$, where $i\epsilon\{1,2\}$.

Proposition 3 states the price in the monopoly stage is always higher than the optimal price in the duopoly stage when the overcapacity is relatively low, i.e., $0 < \lambda < \frac{1}{2}$. Here when λ is relatively small, both the BRF slopes of Port 1 and Port 2 are positive as shown in Figure 4-1(a). Since Port 1 drives Port 2 out of the market, Port 1 will decide the optimal prices at two sites to maximize total profit. This finding is the constant with the results in Chapter 3, which reveals the price in cooperation is always higher than that in competition when the two ports provide substitute service. Proposition 3 will be proved in Appendix B.

Proposition 4. $\Pi_m > {\Pi_1}^*$, and ${\Pi_1}^* > {\Pi_1}^0$, if $0 < \lambda < \frac{1}{2}$.

Proposition 4 states that the optimal profit of Port 1 in monopoly stage is always higher than that in duopoly stage when the overcapacity is relatively small. And at the point when Port 1 drives Port 2 out of the market, the profit also decreases. Due to the lengthy calculation process of profit functions, the proof of Proposition 5 can be found in Appendix C.

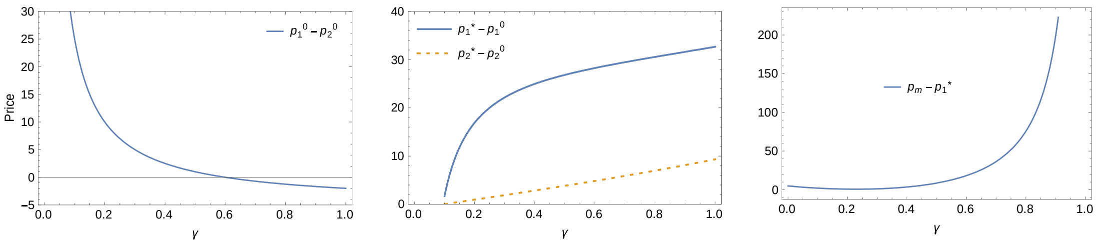
Based on the above analysis, we find that if Port 1 (with a larger number of loyal customers) wants to drive Port 2 (with a smaller number of loyal customers) out of the market, the price reduction should always be higher than that of its competitor. At the point where the competitor is driven out, the price of Port 1 may be higher or lower than that of Port 2, depending on the comparison of average marginal cost and Port 2's weighted loyal customers. After driving the competitor out of the market, whether the profit gain ($\Pi_m - {\Pi_1}^*$) in monopoly stage can compensate the profit loss (${\Pi_1}^* - {\Pi_1}^0$) in predatory price process cannot not be compared directly by the theoretical results, therefore, we will use numerical simulations to further analyze the results.

4.5 Numerical analysis

Since we cannot directly compare the throughput and profit changes from duopoly to monopoly with the theoretical results, here we use numerical examples to show the results and draw conclusions. Therefore, numerical examples will be presented to explain the theoretical results and examine how the substitute relationship (γ) and overcapacity (λ) influence the change of price, throughput and profit from duopoly to monopoly stage.

4.5.1 Numerical analysis of $\boldsymbol{\gamma}$

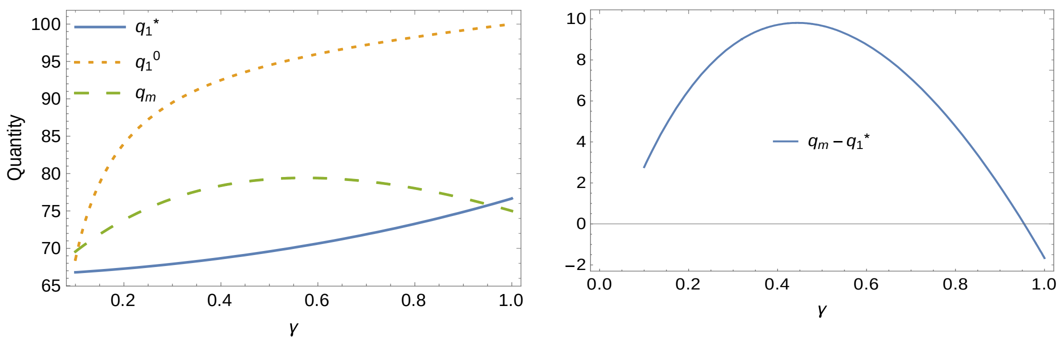
To explore the effect of the substitutability of the two ports (γ) on the theoretical results and simplify the simulation process, here we assume $\bar{x} = 100$, $\alpha_1 = 0.98$, $\alpha_2 = 0.02$, $c = 5$, $\lambda = 0.3$, and $\gamma \epsilon (0,1)$. The initial market share of Port 1 should be considerably larger than that of Port 2, then Port 1 can have the ability to drive Port 2 out of the market. The parameters c and λ should satisfy the conditions to ensure a positive marginal utility. We use ${p_1}^0$ and ${p_2}^0$ to represent the price at the point where Port 1 drive Port 2 out of the shipping market, δp_1 and δp_2 indicate the price reduction of Port 1 and Port 2. Then ${p_1}^*$, p_m states the optimal price of Port 1, ${q_1}^*$, q_m represent optimal throughput of Port 1, and ${\Pi_1}^*$, Π_m represent the optimal profit of Port 1 in duopoly and monopoly stage, respectively. The numerical results are presented in Figure 4-4 to Figure 4-6.



(a) (b) (c)

Figure 4-4 The impact of γ on price

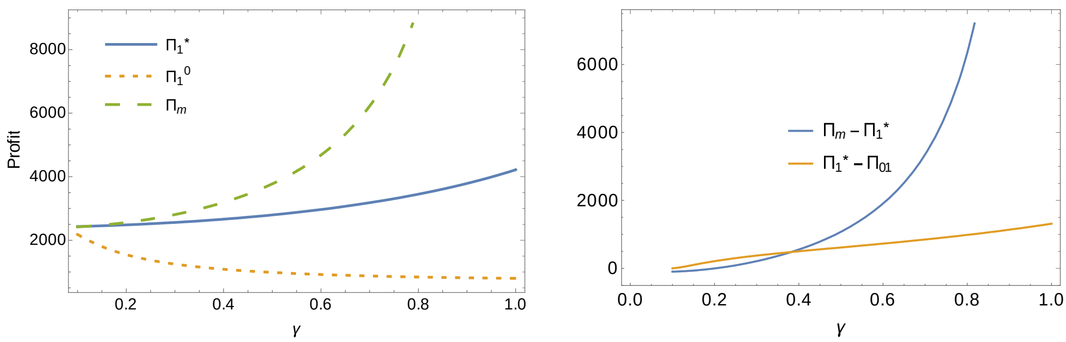
As shown in Figure 4-4, the simulated price change is consist with the theoretical results. First, as shown in Figure 4-4 (a), when the substitutability is relatively low, the price of Port 1 is always higher than that of Port 2 at the point where Port 1 drives Port 2 out of the market; when the substitutability is relatively high, the price of Port 1 is lower than that of Port 2. Figure 4-4 (b) shows the price reduction of Port 1 is always larger than that of Port 2 for the predatory price to be effective. With the increase of substitutability (γ), the difference in the price reductions of the two ports become higher. In other words, when the services provided by the two ports are close substitutes, Port 1 should reduce its price more to drive Port 2 out of the market. In Figure 4-4 (c), the optimal price of Port 1 in monopoly stage is always higher than that in duopoly market, the higher the substitutability, the larger the optimal price gap between the two stages. It can be concluded that when the services provided by the two ports are similar, the optimal price in monopoly stage can be much higher than that in duopoly competition.



(a) (b)

Figure 4-5 The impact of γ on throughput

Figure 4-5 shows that the trends of throughput change of Port 1 from duopoly to monopoly stage. In Figure 4-5 (a), the optimal throughput for Port 1 in monopoly stage is higher than that in duopoly stage most of the time; when the substitutability is very high, the throughput in monopoly can be lower than that in duopoly competition. In addition, the increase in substitutability (γ) between the two ports always increases the throughput for Port 1 in both duopoly competition and predatory price process, while the optimal throughput in monopoly stage will experience increase first and then fall down. That is because when Port 1 obtain the monopoly power, it will provide the service for both its own customers and the customers originally serviced by Port 2, therefore the throughput in monopoly stage will be higher than that in duopoly stage for Port1 most of the time. In Figure 4-5 (b), we find the gap of optimal throughput for Port 1 from duopoly to monopoly will increase first and then decrease with the increase of substitutability.



(a) (b)

Figure 4-6 The impact of γ on profit

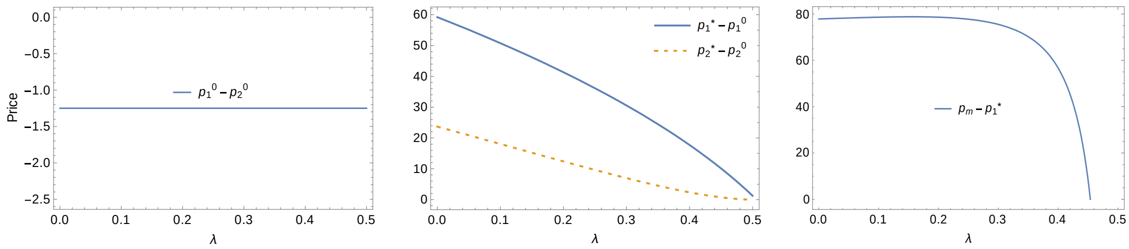
Figure 4-6 shows the trend of profit change of Port 1 from duopoly to monopoly with the increase of substitutability (γ). First, Figure 4-6 (a) shows the optimal profit of Port 1 in monopoly is higher than that in duopoly stage. Second, with the increase of substitutability between the two ports, the optimal profit in both duopoly and monopoly always increase, while the profit in the predatory price process decrease with the increase of substitutability between the two ports. In Figure 4-6 (b), we can find both the profit loss ($\Pi_1{}^* - \Pi_1{}^0$) in predatory price process and the profit gain ($\Pi_m - \Pi_1{}^*$) in monopoly stage always increase with the increase of the substitutability. Moreover, the profit gain is not always higher than the profit loss for Port 1. When the substitutability is relatively low, the profit loss for Port 1 in the predatory price process is higher than the profit gain in monopoly stage. When the substitutability is relatively high, the profit gain in monopoly stage can compensate the profit loss for driving Port 2 out of the market. This indicates when the service provided by the two ports are relatively high, it is profitable for Port 1 to drive Port 2 out of the market, and obtain the monopoly power.

From the above discussion, we can conclude that when the services provided by the two ports are different (γ is relatively small), Port 1 is more easier to drive Port 2 out of the market by losing less profit. With the increase of the substitutability between the two ports, Port 1 needs to loss more profit to drive Port 2 out of the market. However, when the substitutability is small, even if Port 1 obtains the monopoly stage, the profit gain in monopoly stage cannot compensate the profit loss for driving Port 2 out of the market. In a very high substitutability between the two ports, the throughput in monopoly stage can be lower than that in duopoly competition for Port 1, because the price can be set very high in monopoly stage in this condition.

Therefore, considering the price, throughput and profit changes using predatory pricing, when the substitutability between the two ports is low, it is not profitable for the dominating port to drive its competitor out of the market. When the service provided by the two ports are relatively similar, it is profitable for Port 1 to completely drive Port 2 out of the market and obtain the monopoly power.

4.5.2 Numerical analysis of $\boldsymbol{\lambda}$

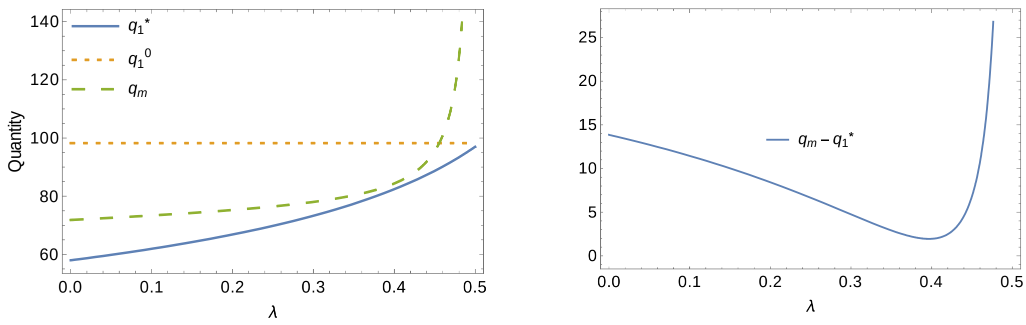
To explore how the price, throughput and profit change with the change of overcapacity (λ) from duopoly to monopoly, we setup $\bar{x} = 100$, $\alpha_1 = 0.98$, $\alpha_2 = 0.02$, $c = 5$, the same setting with Section 4.5.1. Two ports are assumed to have a high degree of substitutability, hence it is assumed that $\gamma = 0.8$. λ is assumed to change from 0 to 0.5, to satisfy the condition for Port 1 to be able to drive Port 2 out of the market. The numerical simulation results are presented in Figure 4-7 to Figure 4-9.



(a) (b) (c)

Figure 4-7 The impact of λ on price

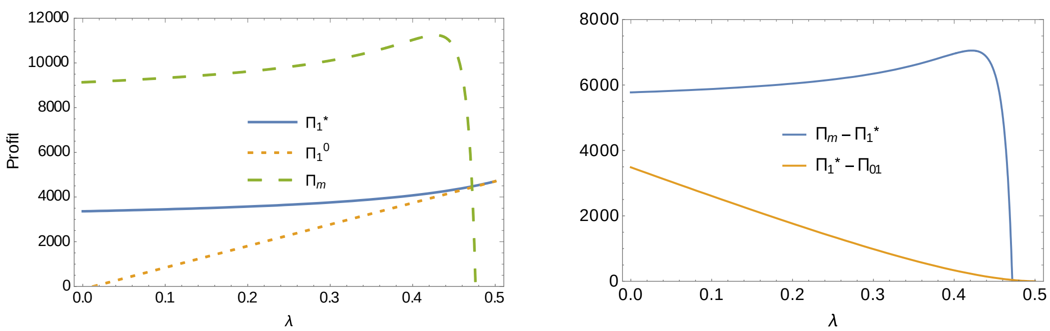
Figure 4-7 (a) illustrates that when the substitutability is high ($\gamma = 0.8$), the price of Port 1 is always lower than that of Port 2 when Port 1 is able to drive Port 2 out of the market. The price gap between Port 1 and Port 2 will not change with the level of overcapacity (λ). In Figure 4-7 (b), the price reduction for Port 1 is always higher than that in Port 2, and the gaps become smaller with the increase of overcapacity. It can be concluded that the higher the overcapacity, the less price reduction is required to drive Port 2 out of the market. In Figure 4-7 (c), the price in monopoly is always higher than that in duopoly for Port 1, and the higher the overcapacity, the smaller the optimal price gap. Therefore, we conclude that with the increase of port overcapacity, even though Port 1 can reduce less price to drive Port 2 out of the market, while when it obtain the monopoly stage, Port 1 can be more difficult to increase its price in monopoly stage.



(a) (b)

Figure 4-8 The impact of λ on throughput

As shown in Figure 4-8 (a), with the increase of port overcapacity(λ), both the optimal throughput of Port 1 in duopoly and monopoly stage increase, while the throughput at successful predatory price does not change. In Figure 4-8 (b), the throughput gap between the monopoly port and the dominating port decreases first and then increase. Therefore, with the increase of port overcapacity, the adoption of predatory pricing can bring high throughput to the dominating port.



(a) (b)

Figure 4-9 The impact of λ on profit

Figure 4-9 shows the profit change of duopoly, predatory pricing, and monopoly with the change of overcapacity level. While the profit for Port 1 in duopoly and predatory pricing increase with λ. The profit in monopoly stage will increase first and decrease suddenly when the overcapacity is relatively high (left figure). The profit gain in the monopoly is mostly much higher than profit loss due to the predatory pricing (right figure), except when the level of overcapacity level is high. Therefore, we can conclude that in a relatively high overcapacity, it is not profitable for Port 1 drive Port 2 out of the market.

In a word, the simulation results help us get more insights over the theoretical results. The substitutability between the two ports and port overcapacity have different impacts on the price, throughput and profit change when predatory pricing is used to drive the competitor out of the market. The higher the substitutability, it is more difficult for Port 1 to drive Port 2 out of the market, because with a high substitutability, Port 1 needs to reduce the price more and lose more profit to achieve the objective. While with the increase of substitutability, the profit gain in monopoly stage can compensate the profit loss when adopting predatory price. However, the impacts of port overcapacity on the theoretical results are different. The higher the degree of overcapacity, the easier for Port 1 to drive Port 2 out of the market, because with the increase of overcapacity, Port 1 can reduce less price and loss less profit when adopting predatory price. In addition, after obtain a monopoly stage, the price and profit in monopoly stage are higher than those in duopoly stage most of the time, except when the overcapacity is relatively high.

Therefore, we conclude that when there exists relatively high overcapacity with a high substitutability between the ports, it is feasible for dominating port to use predatory pricing to drive competitor out of the market. Especially, when the service provided by the two ports are similar or the overcapacity is relatively high, the profit gain for port 1 in monopoly is larger than the profit loss when adopting the predatory price.

4.6 Discussions and policy implications

In this study, the port pricing strategies in a duopoly market are investigated. The Bertrand game theory is applied to examine how can one port drive its competitor out of the market by predatory pricing strategy when the two competitive ports have different initial market shares and provided differentiated services. The objective is to analyze whether the predatory price strategy is feasible in the port market and whether the profit gain after monopoly can compensate the losses when applying the predatory pricing. In addition, the impacts of substitutability and port overcapacity on the equilibrium results are analyzed.

Following the decision -making process for one port to drive its competitor out of the market, a theoretical model is designed to analyze the feasibility for one port to drive its competitor out of the market. A benchmark scenario is setup where two ports compete in Bertrand fashing. A two-stage model is for the purpose of analyzing the feasibility. In the first stage, the dominating port with high initial market share (Port 1) adopts predatory price to drive its competitor (Port 2) out of the market. In this stage, we analyzed what is the necessary condition for the predatory price to drive the competitor out of the shipping market. In the second stage, after the domination port gained monopoly power, the monopoly price, quantity and profit are analyzed. Finally, we compared the equilibrium results in monopoly and duopoly and conducted a numerical simulation to examine the impacts of the substitutability and overcapacity on the results. The conclusions and some policy implications are as follows.

First, the theoretical results revealed that the necessary condition for predatory price to be effective is positive slopes in the two best response functions. In addition, it is found that the price reduction of the dominating port should be larger than the competitor. However, the price of the dominating port may be higher or lower than its competitor, depending on the substitutability between the two ports. When the substitutability is relatively low, the price of the dominating port can be higher than that of the competitor. If the substitutability is relatively high, it could be the opposite.

Second, after the dominating port obtained the market power, the optimal price, throughput and profit of the monopoly are mostly higher than the Bertrand equilibriums. It is worth noting that the level of substitutability and overcapacity have different impacts on the change of price, throughput and profit of the two ports. With the increase of substitutability, the price and profit gaps increase with the formation of monopoly. However, the throughput increases first and then decreases with the change of the substitutability. Moreover, the higher the substitutability, the predatory pricing will result in large profit loss for the dominating port. In addition, the profit gain in monopoly can offset loss in predatory pricing if the substitutability is relatively high. The results indicate that in high substitutability, it is feasible to use predatory price to drive competitors out of the market. For the level of overcapacity, it should be between 0 and 0.5 to enable the predatory price to be effective. With this range, the higher the overcapacity, the easier for the dominating port to drive the other out of the market. With the increase of overcapacity, the profit loss due the adoption of predatory price will decrease. The profit gain after forming the monopoly can offset the loss due to the adoption of predatory pricing strategy when the substitutability is high or there exists large overcapacity.

Third, it is found that when the dominant port drives its competitor out of the market, and obtain the monopoly market, both the optimal price and profit in monopoly are higher than those equilibriums in Bertrand competition. In low substitutability and low overcapacity, it is not profitable for the dominant port to adopt predatory price to drive its competitor out of the market.

This study can provide some useful suggestions for both public policies and private port operators in port management. From the perspective of government policies, when formulating policies, more attention should be paid to the issue of preventing predatory pricing, as this practice can lead to market monopolies and result in a reduction of social welfare. Meanwhile, for private port operators, when considering the adoption of predatory pricing, they need to fully consider the substitutability of two ports and the supply-demand relationship of port services in the region, in order to better control market prices and avoid unfair price differentials. Therefore, private port operators should formulate reasonable pricing strategies based on market demand and actual conditions, to ensure the fairness and sustainability of market competition.

4.7 Chapter summary

In the context of port competition in China, this study explored whether port price-cutting competition is malicious, and whether price-cutting competition in port market should be banned. Specially, we considered a duopoly port market where each port has different market share, the service is not homogeneous, nor are they perfect substitute, and there exists overcapacity. An analytical model based on Bertrand competition is designed to examine the predatory pricing decision. In the first stage, the dominant port with a higher initial market share adopts predatory price. In the second stage, the dominant port become a monopoly, and decides the optimal pricing at both ports to maximize the total profit. The impacts of substitutability and overcapacity on the equilibrium results are analyzed with a theoretical comparison and a numerical simulation.

First, predatory price strategy for ports in port market can be feasible in certain circumstance, especially when the ports are in high substitutable or there exists high overcapacity. Second, for the ports with a large initial market share, the best strategy is to enhance their competitiveness to reduce profit losses in the process of driving the competitors out of the market. Third, taking the duopoly market as an example, the study shows that it can be profitable for the dominating port to completely drive its competitors out of the market. The monopoly port can operate the facilities at both ports, and decide the optimal prices to maximize total profit. The research findings show that in a highly competitive port market, price competition is not a problem. Predatory price is. Reginal ports should revitalize the market through cooperation-competition to achieve a win-win situation. Studying the pricing decision making process and social consequence of predatory pricing in port competition, together with the effects of substitutability and overcapacity, will provide additional insight into the formation of public polices when faced with market transition and evolution.

Chapter 5 Conclusions and Limitations

5.1 Conclusions and Contributions

In the environment of overcapacity and underutilization of port resources in multi-port regions in China, this thesis explores the research on port competition, cooperation and integration. We attempt to answer three questions: What's the relationship among port competition, cooperation and competitiveness in current studies? Whether the regional ports should cooperate or compete and whether the port integration is necessary? How does predatory price strategy arise in port market, and is it profitable for one port to use predatory price to drive its competitor out of the market? The aim of this thesis is to analyze the impact of internal and external conditions on port competition strategies, explore ways and methods to enhance port competitiveness, and provide new perspectives and decision-making references for the sustainable development of port management. Through a comprehensive analytical framework, the main conclusions, managerial insights and contributions of each question are as follows.

In research question 1, we give a review of current research into identifying the relationships among port competition, cooperation and competitiveness. Although the number of studies on these three topic areas has increased significantly in recent decades, the relationship among them has not been sufficiently clarified. Our study attempts to identify the relationship among the three through a comprehensive literature review of 210 journal papers in these three fields from 1970 to 2019, as well as research on overlapping topics. The major findings are as follows. First, the extant research on port competition and cooperation relationships is mainly conducted from the perspective of ports, and there is little evaluation of the implications of these strategies from other perspectives, especially from social point of view. Second, on the relationship of port competition and competitiveness, a widely view is that intra-port competition can increase the competitiveness of the port. Actually, some also found that both inter-port competition and cooperation are found to have positive or negative impacts, depending on the perspective of the study and the geographical location of the ports in question. Third, on the relationship of port cooperation and competitiveness, we found the cooperation among adjacent ports can improve their competitiveness when they are facing a new external competitor. Since both competition and cooperation can enhance port competitiveness, then how to maintain investors' interests if a higher level of competition results in a low profit margin? How to prevent the possible inefficiency when the level of competition is not enough?

The research findings of this question is critical for both port operations and public interests. From the private port business perspective, improving competitiveness is a must to attract both investors and customers, and to be successful in today's competitive environment. Since competition can drive down profit margin and cooperation may result in inefficiency, which strategy to adopt is critical for port operations, which requires a better understanding on the relationship among these three aspects. From government point of review, competition is usually preferred by consumers because it can reduce uses' cost and increase shippers' benefit. Therefore, balance the ports profit and shippers benefit considering port competition and cooperation, it is critical to investigate the relationship s among port competition, cooperation and competitiveness. Especially for China, as many coastal ports are actively following the government policy for "one Province one port group". Therefore, our study contributes to a better understanding of how ports can improve their competitiveness in increasingly interconnected markets and how competitive or cooperative strategies affect port competitiveness.

In research question 2, based on the review on the relationships among port competition, cooperation and competitiveness, we examine the best port management strategies (cooperative or non-cooperative, in short, CO or NC) from the perspective of ports, shippers as well as society, considering different combination of port attribute and shippers' preference, including whether there exists overcapacity or congestion and whether the relationship of the ports are complements or substitutes. Social-welfare maximization is used as a benchmark to compare the result in CO or NC in this study, theoretical analysis and numerical simulation are conducted to illustrate the results. Our major findings are as follows. First, ports prefer cooperate naturally, as it can generate maximum total profit for ports. NC is beneficial to shippers when the two ports are substitutes, as competition can result in lower price, higher total throughput, consumer surplus and social welfare. From the perspective of government, NC should be encouraged when the two ports provide substitutable services. In addition, CO can lead to monopoly and social welfare losses. Such losses increase with the level of overcapacity compared with NC. Hence CO should be prevented among substituting ports. Considering the benefit allocation between shippers and ports, the port profit is always higher than shippers' benefit in CO when two ports are complement relationships if the overcapacity is not so big. While when the two ports provide substitute service, port profit can be lower than the shipper's benefit, especially when the substitutability and congestion level are high.

This study contributes to the theory in competition/cooperation by considering the equilibrium outcomes with different combinations of port attribute and shippers' preference in a duopoly environment. It points out that for complement services, cooperation can generate higher social welfare, which is similar to the prevention of double marginalization in vertically integrated supply chain(Hamilton and Ibrahim, 1996). In addition, it explicitly identifies the benefit allocation between consumers and suppliers among all possible combinations of port attribute and shippers' preference. This information is critical for decision makers in considering the affected parties (consumer or suppliers) for any changes in these conditions.

In research question 3, we analyze the feasibility of predatory pricing in port competition. In brief, a theoretical model is constructed based on Bertrand game to analyze how one port uses predatory pricing to drive its competitor out of the market, to examine whether price-cutting competition is feasible in the shipping market. We consider a duopoly port market where each port has different initial market share. The two ports in the market are not perfect substitutes, and there exists overcapacity. The major research findings are as follows. First, when dominating port (the one with higher initial market share) drives the competitor (the one with lower initial market share) out of the market, the dominating port will reduce its price much more than its competitor compared with the Bertrand equilibrium prices. However, whether the price of dominating port is higher or lower than that of the competitor depends on the substitutability. Second, at forming monopoly, the optimal price, throughput and profit are larger than the Bertrand equilibriums. Third, compared with the Bertrand equilibrium, the profit gain for dominating port in monopoly can offset the profit loss due to the adoption of predatory pricing when the substitutability is high or there exist large overcapacity. Otherwise, the profit gain in monopoly cannot compensate for the profit loss. Therefore, we conclude that when there exists relatively high overcapacity with a high substitutability between the ports, it is feasible for one port with a higher market share to use predatory pricing to drive the competitor out of the market.

This study can provide some useful suggestions for both public policies and private port operators in port management. For government policies, it is necessary to prevent the predatory pricing, as it can form monopoly and result in social welfare loss. For private port operators, when consider adopting predatory pricing, it is necessary to consider the substitutability of the two ports and supply-demand relationship of the port services in the region.

5.2 Limitations and future studies

This thesis investigates the research on port competition, cooperation and integration, our research findings can be useful for both public policies and private port operators in port management, it still has some limitations, which can be considered in further research.

Our model included only two identical ports. If more ports are involved, it is possible that the cooperation can be not stable, and cooperation may happen only among a subsection of the players. In this case, cooperative game-theory model should be used to analyze the possible implications on the social welfare for different combination of the shippers' preference and port attribute.

Due to the data limitation, both in study 2 and study 3, we used hypothetical parameter values in the numerical simulation. It could be improved by using real-world port data to verify the conclusions from the theoretical analysis. In addition, regarding the relationship between port substitutability and complementarity, there is a lack of data and empirical research support. Next, specific case studies should be conducted to further verify the relationships between ports, which will provide a foundation for future in-depth research on port competition and cooperation.

Finally, as there are many different kinds of ports in a province, the impacts of port integration policy may need several years to development. Although Yang, Luo and Wu (2022) has studied the impacts of port integration policy on port productivity, its impacts on the shippers' benefits is not included. This can also be an interesting topic for further research.

Appendixes

Appendix A. Comparative statics analysis of the equilibrium outcomes w.r.t. λ and θ in Chapter 4

A.1: The equilibrium outcomes w.r.t. λ

For $\frac{\partial p_i^{(\cdot)}}{\partial \lambda}$,

$\frac{\partial p_i^{NC}}{\partial \lambda} = \frac{b(1+\theta)(a-c)}{(-2b-b\theta+b\theta^2-\lambda)^2} > 0$, $\frac{\partial p_i^{CO}}{\partial \lambda} = \frac{b(1+\theta)(a-c)}{(2b+2b\theta+\lambda)^2} > 0$, $\frac{\partial p_i^{SO}}{\partial \lambda} = \frac{b(1+\theta)(a-c)}{(b+b\theta+\lambda)^2} > 0$.

For $\frac{\partial q_i^{(\cdot)}}{\partial \lambda}$,

$\frac{\partial q_i^{NC}}{\partial \lambda} = -\frac{a-c}{(2b(1+\theta)-b\theta(1+\theta)+\lambda)^2} < 0$, $\frac{\partial q_i^{CO}}{\partial \lambda} = -\frac{a-c}{(2b(1-\theta)+\lambda)^2} < 0$, $\frac{\partial q_i^{SO}}{\partial \lambda} = -\frac{a-c}{(b(1+\theta)+\lambda)^2} < 0$.

For $\frac{\partial \pi^{(\cdot)}}{\partial \lambda}$,

$\frac{\partial \pi^{NC}}{\partial \lambda} = -\frac{(a-c)^2[b(1+\theta)(2-3\theta)+\lambda]}{(b(2-\theta)(1+\theta)+\lambda)^3}$,

if $b(1+\theta)(2-3\theta)+\lambda < 0$, $\frac{\partial \pi^{NC}}{\partial \lambda} > 0$; if $b(1+\theta)(2-3\theta)+\lambda > 0$, $\frac{\partial \pi^{NC}}{\partial \lambda} < 0$.

$\frac{\partial \pi^{CO}}{\partial \lambda} = -\frac{(a-c)^2}{(2b(1+\theta)+\lambda)^2} < 0$,

$\frac{\partial \pi^{SO}}{\partial \lambda} = -\frac{(a-c)^2(-b-b\theta+\lambda)}{(b+b\theta+\lambda)^3}$, if $b(1+\theta) > \lambda$, $\frac{\partial \pi^{SO}}{\partial \lambda} > 0$; if $b(1+\theta) < \lambda$, $\frac{\partial \pi^{SO}}{\partial \lambda} < 0$.

For $\frac{\partial CS^{(\cdot)}}{\partial \lambda}$,

$\frac{\partial CS^{NC}}{\partial \lambda} = -\frac{2b(a-c)^2(1+\theta)}{(b(2-\theta)(1+\theta)+\lambda)^3} < 0$, $\frac{\partial CS^{CO}}{\partial \lambda} = -\frac{2b(a-c)^2(1+\theta)}{(2b(1+\theta)+\lambda)^3} < 0$, $\frac{\partial CS^{SO}}{\partial \lambda} = -\frac{2b(a-c)^2(1+\theta)}{(b(1+\theta)+\lambda)^3} < 0$.

For $\frac{\partial SW^{(\cdot)}}{\partial \lambda}$,

$\frac{\partial SW^{NC}}{\partial \lambda} = -\frac{(a-c)^2(b(1+\theta)(1+3b(1-\theta))+\lambda)}{(b(2-\theta)(1+\theta)+\lambda)^3} < 0$,

$\frac{\partial SW^{CO}}{\partial \lambda} = -\frac{(a-c)^2(4b+4b\theta+\lambda)}{(2b+2b\theta+\lambda)^3}$, as $(4b+4b\theta+\lambda) > (2b+2b\theta+\lambda) > 0$, then $\frac{\partial SW^{CO}}{\partial \lambda} < 0$.

$\frac{\partial SW^{SO}}{\partial \lambda} = -\frac{2(a-c)^2}{(b+b\theta+\lambda)^3} < 0$.

A.2: The equilibrium outcomes w.r.t. θ

For $\frac{\partial p_i^{(.)}}{\partial \theta}$,

$\frac{\partial p_i^{NC}}{\partial \theta} = \frac{-b[b(1+\theta)^2+\lambda](a-c)}{(2b(1+\theta)-b\theta(1+\theta)+\lambda)^2}$, if $\lambda > -b(1+\theta)^2$, $\frac{\partial p_i^{NC}}{\partial \theta} < 0$; if $\lambda < -b(1+\theta)^2$, $\frac{\partial p_i^{NC}}{\partial \theta} > 0$.

$\frac{\partial p_i^{CO}}{\partial \theta} = \frac{-b\lambda(a-c)}{(2b+2b\theta+\lambda)^2}$, if $\lambda < 0$, $\frac{\partial p_i^{CO}}{\partial \theta} > 0$; if $\lambda > 0$, $\frac{\partial p_i^{CO}}{\partial \theta} < 0$

$\frac{\partial p_i^{SO}}{\partial \theta} = \frac{-b\lambda(a-c)}{(b+b\theta+\lambda)^2}$, if $\lambda < 0$, $\frac{\partial p_i^{SO}}{\partial \theta} > 0$; if $\lambda > 0$, $\frac{\partial p_i^{SO}}{\partial \theta} < 0$.

For $\frac{\partial q_i^{(.)}}{\partial \theta}$,

$\frac{\partial q_i^{NC}}{\partial \theta} = -\frac{b(a-c)(1-2\theta)}{(2b(1+\theta)-b\theta(1+\theta)+\lambda)^2}$, if $\theta > \frac{1}{2}$, $\frac{\partial q_i^{NC}}{\partial \theta} > 0$; if $\theta < \frac{1}{2}$, $\frac{\partial q_i^{NC}}{\partial \theta} < 0$.

$\frac{\partial q_i^{CO}}{\partial \theta} = -\frac{2b(a-c)}{(2b(1+\theta)+\lambda)^2} < 0$, $\quad \frac{\partial q_i^{SO}}{\partial \theta} = -\frac{b(a-c)}{(b(1+\theta)+\lambda)^2} < 0$

For $\frac{\partial \pi^{(.)}}{\partial \theta}$,

$\frac{\partial \pi^{NC}}{\partial \theta} = -\frac{2(a-c)^2 b(2b(1+\theta^3)+\lambda)}{(b(2-\theta)(1+\theta)+\lambda)^3} < 0$, $\frac{\partial \pi^{CO}}{\partial \theta} = -\frac{2b(a-c)^2}{(2b(1+\theta)+\lambda)^2} < 0$,

$\frac{\partial \pi^{SO}}{\partial \theta} = -\frac{2b(a-c)^2\lambda}{(b(1+\theta)+\lambda)^3}$, if $\lambda < 0$, $\frac{\partial \pi^{SO}}{\partial \theta} > 0$; if $\lambda > 0$, $\frac{\partial \pi^{SO}}{\partial \theta} < 0$.

For $\frac{\partial CS^{(.)}}{\partial \theta}$,

$\frac{\partial CS^{NC}}{\partial \theta} = -\frac{b(a-c)^2[3b\theta(1+\theta)+\lambda]}{(b(2-\theta)(1+\theta)+\lambda)^3}$,

if $3b\theta(1+\theta)+\lambda < 0$, $\frac{\partial CS^{NC}}{\partial \theta} > 0$; if $3b\theta(1+\theta)+\lambda > 0$, $\frac{\partial CS^{NC}}{\partial \theta} < 0$.

$\frac{\partial CS^{CO}}{\partial \theta} = -\frac{(a-c)^2 b(2b(1+\theta)-\lambda)}{(2b+2b\theta+\lambda)^3}$,

if $\lambda > 2b(1+\theta)$, $\frac{\partial CS^{CO}}{\partial \theta} > 0$; if $\lambda < 2b(1+\theta)$, $\frac{\partial CS^{CO}}{\partial \theta} < 0$.

$\frac{\partial CS^{SO}}{\partial \theta} = -\frac{(a-c)^2 b(b(1+\theta)-\lambda)}{(b+b\theta+\lambda)^3}$

if $\lambda > b(1+\theta)$, $\frac{\partial CS^{SO}}{\partial \theta} > 0$; if $\lambda < b(1+\theta)$, $\frac{\partial CS^{SO}}{\partial \theta} < 0$.

For $\frac{\partial SW^{(.)}}{\partial \theta}$,

$\frac{\partial SW^{NC}}{\partial \theta} = -\frac{(a-c)^2 b[b(1+\theta)(4\theta^2-7\theta+4)+\lambda]}{(b(2-\theta)(1+\theta)+\lambda)^3}$

if $b(1+\theta)(4\theta^2-7\theta+4)+\lambda < 0$, $\frac{\partial SW^{NC}}{\partial \theta} > 0$;

if $b(1+\theta)(4\theta^2-7\theta+4)+\lambda > 0$, $\frac{\partial SW^{NC}}{\partial \theta} < 0$.

$$\frac{\partial SW^{CO}}{\partial \theta} = -\frac{b(a-c)^2(6b+6b\theta+\lambda)}{(2b+2b\theta+\lambda)^3} < 0,\ \frac{\partial SW^{SO}}{\partial \theta} = -\frac{2b(a-c)^2}{(b+b\theta+\lambda)^3} < 0.$$

Appendix B. The proof of proposition 3 in Chapter 5 is as follows:

Since the best response function of Port1 in Bertrand competition is,

$$p_1{}^*(p_2) = \frac{(1-2\lambda)\alpha_1\bar{x}+\gamma(1-2\lambda)p_2+c}{2(1-\lambda)},$$

Therefore, the slope of the Best Response Functions (BRFs) and intercept for Port 1 in Bertrand competition in Figure 4-3 can be expressed as,

$$\frac{\partial p_1{}^*}{\partial p_2} = \frac{\gamma(1-2\lambda)}{2(1-\lambda)},\ A^* = \frac{(1-2\lambda)\alpha_1\bar{x}+c}{2(1-\lambda)}$$

The best response function of Port1 in Monopoly stage is,

$$p_1{}^m(p_2) = \frac{[(1-2\lambda)\alpha_1+2\lambda\gamma\alpha_2]\bar{x}+c(1-\gamma)+2[\gamma-\lambda(1+\gamma)]p_2}{2[1-\lambda(1+\gamma)]},$$

Therefore, the slope of the Best Response Functions (BRFs) and intercept for Port 1 in Monopoly stage in Figure 4-3 can be expressed as,

$$\frac{\partial p_1{}^m}{\partial p_2} = \frac{\gamma-\lambda(1+\gamma)}{1-\lambda(1+\gamma)},\ A^m = \frac{[(1-2\lambda)\alpha_1+2\lambda\gamma\alpha_2]\bar{x}+c(1-\gamma)}{2[1-\lambda(1+\gamma)]}.$$

Then, we can obtain,

$$\frac{\partial p_1{}^m}{\partial p_2} - \frac{\partial p_1{}^*}{\partial p_2} = \frac{\gamma-\lambda(1+\gamma)}{1-\lambda(1+\gamma)} - \frac{\gamma(1-2\lambda)}{2(1-\lambda)} = \frac{(\gamma-2\lambda)(1-\lambda)+\gamma^2\lambda(1-2\lambda)}{2(1-\lambda)[1-\lambda(1+\gamma)]}$$

$$A^M - A^* = \frac{[(1-2\lambda)\alpha_1+2\lambda\gamma\alpha_2]\bar{x}+c(1-\gamma)}{2[1-\lambda(1+\gamma)]} - \frac{(1-2\lambda)\alpha_1\bar{x}+c}{2(1-\lambda)}$$

$$= \frac{(-c\gamma+2c\gamma\lambda+\bar{x}\gamma\lambda-2\bar{x}\gamma\lambda^2+\alpha_2\bar{x}\lambda\gamma)}{2(1-\lambda)[1-\lambda(1+\gamma)]} = \frac{\gamma[(\lambda\bar{x}-c)(1-2\lambda)+\lambda\alpha_2\bar{x}]}{2(1-\lambda)[1-\lambda(1+\gamma)]}$$

As $0 < \gamma < 1$, $\alpha_1 = 1-\alpha_2$, $0 < \lambda < \frac{1}{2}$, then the equilibrium point in monopoly stage can always be higher than the equilibrium point in Bertrand competition in duopoly market, therefore, $p_1{}^m > p_1{}^*$, which means when Port1 obtain the monopoly stage, the monopoly price is always higher than that in duopoly competition.

Appendix C. The proof of proposition 4 in Chapter 5 is as follows:

As we calculate, in the process of Port 1 driving Port 2 out of the market,

$$\nabla p = p_1{}^* - p_1{}^0 > 0,\ \nabla q = q_1{}^* - q_1{}^0 < 0.$$

Hence, the profit loss in duopoly stage:

$$\Pi_1{}^* - \Pi_1{}^0 = p_1{}^*q_1{}^* - C(q_1{}^*) - [p_1{}^0q_1{}^0 - C(q_1{}^0)]$$

$$= p_1{}^*\left(\alpha_1\bar{x} - p_1{}^* + \gamma p_2{}^*\right) - p_1{}^0\left(\alpha_1\bar{x} - p_1{}^0 + \gamma p_2{}^0\right) - \left[c\left(q_1{}^* - q_1{}^0\right) - \lambda\left(q_1{}^{*2} - q_1{}^{02}\right)\right]$$

$= (p_1{}^* - p_1{}^0)\alpha_1\bar{x} - \left(p_1{}^{*2} - p_1{}^{0\,2}\right) + \gamma(p_1{}^*p_2{}^* - p_1{}^0p_2{}^0) - \left[c(q_1{}^* - q_1{}^0) - \lambda\left(q_1{}^{*2} - q_1{}^{0\,2}\right)\right]$

$= \nabla p[\alpha_1\bar{x} - (p_1{}^* + p_1{}^0)] + \gamma(p_1{}^*p_2{}^* - p_1{}^0p_2{}^0) - \nabla q[(c - \lambda q_1{}^*) + (c - \lambda q_1{}^0)] + c\nabla q$

Where $(c - \lambda q_i) > 0$, $\alpha_1\bar{x}$ is the loyal customer of Port 1, which is a large positive number, $[\alpha_1\bar{x} - (p_1{}^* + p_1{}^0)] \gg 0$, and $\nabla p > 0$, $\nabla q < 0$, $|\Delta q|$ is a small number, $p_i{}^* > p_i{}^0$, $p_1{}^*p_2{}^* > p_1{}^0p_2{}^0$, $q_i > 0$. Therefore, when $0 < \lambda < \frac{1}{2}$, $\Pi_1{}^* - \Pi_1{}^0 > 0$, i.e., $\Pi_1{}^* > \Pi_1{}^0$.

The profit gain in monopoly stage:

Obviously, we have $\Delta p = p_1{}^m - p_1{}^* > 0$, $\Delta q = q_1{}^m - q_1{}^* < 0$

$\Pi_m - \Pi_1{}^* = p_1{}^m q_1{}^m - (cq_1{}^m - \lambda q_1{}^{m2}) + p_2{}^m q_2{}^m - (cq_2{}^m - \lambda q_2{}^{m2}) - p_1{}^*q_1{}^* + (cq_1{}^* - \lambda q_1{}^{*2})$

$= p_1{}^m(\alpha_1\bar{x} - p_1{}^m + \gamma p_2{}^m) - p_1{}^*(\alpha_1\bar{x} - p_1{}^* + \gamma p_2{}^*) - \left[c(q_1{}^m - q_1{}^*) - \lambda\left(q_1{}^{m2} - q_1{}^{*2}\right)\right] + p_2{}^m(\alpha_2\bar{x} - p_2{}^m + \gamma p_1{}^m) - (cq_2{}^m - \lambda q_2{}^{m2})$

$= (p_1{}^m - p_1{}^*)\alpha_1\bar{x} - \left(p_1{}^{m2} - p_1{}^{*2}\right) + \gamma(p_1{}^m p_2{}^m - p_1{}^*p_2{}^*) - \left[c(q_1{}^m - q_1{}^*) - \lambda\left(q_1{}^{m2} - q_1{}^{*2}\right)\right] + p_2{}^m(\alpha_2\bar{x} - p_2{}^m + \gamma p_1{}^m) - (cq_2{}^m - \lambda q_2{}^{m2})$

$= \Delta p[\alpha_1\bar{x} - (p_1{}^m + p_1{}^*)] + \gamma(p_1{}^m p_2{}^m - p_1{}^*p_2{}^*) - [c\,\Delta q - \lambda\,\Delta q(q_1{}^m + q_1{}^*)] + p_2{}^m(\alpha_2\bar{x} - p_2{}^m + \gamma p_1{}^m) - (cq_2{}^m - \lambda q_2{}^{m2})$

$= \Delta p[\alpha_1\bar{x} - (p_1{}^m + p_1{}^*)] + \gamma(p_1{}^m p_2{}^m - p_1{}^*p_2{}^*) - [c\,\Delta q - \lambda\,\Delta q(q_1{}^m + q_1{}^*)] + \Pi_2{}^m$

Same as in the previous proof, we can obtain $\Pi_m - \Pi_1{}^* > 0$, i.e., $\Pi_m > \Pi_1{}^*$.

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