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Dissertation for the Degree of Doctor of Philosophy

Modeling of Optimal Concession Contract between Port Authority and Terminal Operators using Channel Coordination Model

Supervisor: Prof. Kim Jae Bong

Ashurov Abdulaziz Rustamovich

Department of International Trade
Graduate School of Korea Maritime & Ocean University

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Approval Sheet

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Approved by the Dissertation Committee:

Yong-Sik Oh, PhD
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Nam-Ki Park, PhD
Member ______________________________

Jae-Bong Kim, PhD
Member ______________________________

Department of International Trade

Graduate School of Korea Maritime and Ocean University

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MODELING OF OPTIMAL CONCESSION CONTRACT BETWEEN PORT AUTHORITY AND TERMINAL OPERATORS USING CHANNEL COORDINATION MODEL

Ashurov Abdulaziz Rustamovich

Department of International Trade
Graduate School of Korea Maritime & Ocean University

Abstract

Rapid changes in the global maritime market have a major impact on the port industry. PA (Port Authority) and TOC (Terminal Operating Company) have invested heavily in port facilities and equipment so far to secure competitive advantage. TOC strives to improve profitability in accordance with requirements from competitors and shipping companies. In the same situation, PA is also looking for its own profitability. Market uncertainty and technological changes require PA and TOC to achieve better financial conditions in cooperation. The ports are operated in different contracts. According to the landlord function model which is operated by 60-70% of the world, the PA owns and manages the land and infrastructure of the port, and the TOC is responsible for terminal operations. The PA and TOC will decide whether to use a fixed fee or a unit fee through the contract. There is no absolute contract method in the port leasing system. Most regions in Asia prefer to use the fixed fee, while European countries prefer to use a mix of fixed fee and unit fee.

There have been few studies on the port leasing system. In particular, most of them did not provide specific calculations or were impractical. On the other hand, previous studies have focused on maximizing profits from the perspective of PA rather than TOC. This research focuses on how to connect to the method of maximizing profit between public and private entities. The four types

of contracts proposed by the PA to the TOC are compared with the uncoordination, coordination, Cournot and Collusion models, and at the same time, model comparisons and numerical analysis are performed for each contract method. The results of the study will have a significant impact on establishing future port lease contracts. Observing the comparative numerical analysis, the following main results are obtained.

According to the results, it can be seen that the two-part tariff is higher than the each of fixed and unit contracts. As the PA shares with the profits and risks in cooperation with the TOC, the TOC can increase throughput, which can maximize the total benefit between PA and TOC. Thus, the PA can make more profits when it comes to providing a contract that is coordination contract provide more than uncoordination contract. And the joint profit of PA and TOC is higher than the respective total profits. Through the joint profit of PA and TOC, the PA can provide the TOC with the appropriate contractual condition and maximize their joint profits. The PA, in cooperation with the TOC, is able to generate profits no matter what contract type it chooses.

항만 공사와 터미널 운영사 간에 채널 코디네이션을 이용한 최적의 임차권 계약서 모델링

아슈로프 압둘라지즈

무역학과

한국해양대학교 대학원

초록

세계 해운 시장의 급격한 변화는 항만 산업에 큰 영향을 미친다. PA (항만공사)와 TOC (터미널 운영 회사)는 경쟁 우위를 확보하기 위하여 지금까지 항만 시설과 장비에 많은 투자를 해왔다. TOC는 경쟁사 및 해운 회사로부터의 요구 사항에 따라 수익성을 제고하기 위해 노력한다. 같은 상황에서 PA도 경쟁력을 찾고 있다. 시장의 불확실성과 기술적 변화는 PA와 TOC가 협력하여 더 나은 재정 상태를 요구하고 있다. PA와 TOC간에는계약을 통해 여러 방식으로 운영된다. 세계의 60-70%가 운영중인 임대 기능 모델에 따르면, PA는 항만의 토지 및 인프라를 소유·관리하며, TOC는 터미널 운영을 담당한다. PA와 TOC는 계약을 통해 고정 요금제 내지 단가 요금제 등의 여부를 결정한다. 세계 항만 임대 시스템을 비교해 볼 때, 절대적인 고정된 계약 방식이 없다고 한다. 아시아의 대부분 지역에서는 고정 요금제를 이용하고, 유럽 지역에서는 고정 요금제와 단가 요금제가 혼합된 계약을 이용한다.

그동안 세계 항만 임대 시스템에 간한 연구는 많지 않았다. 특히 구체적 수치를 제공하

지 않거나 비실용적 연구가 많았다. 한편, 이전 연구에서는TOC보다 PA관점에서의 이익 극대화를 도모하는 데 중점을 두었다. 만약 PA가 처리량을 늘림으로써 이익을 극대화하고자 할 때, 고정 임대 계약이 더 유리한 선택이다. 이 연구는 공공기관과 민간 단체 상호간의 이익 극대화의 방식으로 연결하는 방법에 중점을 두고 있다. PA가 TOC에게 제안하는 4 가지 유형의 계약 방식은 비조정, 조정, Cournot 및 Collusion 모델로 비교하고, 동시에 각 계약 방식에 대해 모듈 수행과 수치 분석을 통해 모델을 비교한다. 연구 결과는 향후 항만 임대 계약을 수립하는 데 중요한 영향을 미칠 것이다. 비교 수치 분석을 관찰하면 다음과 같은 주요 결과를 얻을 수 있다.

결과에 따르면, 고정 계약과 단가 계약을 합친 조건이 각각의 고정 및 단가 계약제 보다 더 높다는 것을 알 수 있다. PA가 TOC의 이익과 위험을 다루는 만큼 TOC가 처리량을 증가시킬 수 있으며, 이것은 PA와 TOC 간의 총이익을 극대화 할 수 있다. 따라서PA가 조정 없는 계약을 제공하는 것보다 조정된 계약을 제공 할 때 더 많은 이익을 낼 수 있다. 그리고 PA와 TOC의 통합 이익은 각각의 이익보다 더 높다. PA와TOC의 통합 이익을 통해서 PA는 TOC에게 적절한 계약 방식을 제공하고 상호간의 이익 극대화를 도모할 수 있다. PA가 이익을 늘리려고 시도 할 때마다 수익과 수요 위험을 공유함으로써 TOC와의 관계를 유지해야한다. PA는TOC와의 협조로 어떤 계약방식을 선택하더라도 이익을 창출할 수 있다.

Chapter 1. Introduction

1. Background

Recent transforms in port industry

The seaports handle over 80% of global trade by volume and more than 70% of its value of the worldwide (UNCTAD, 2017). In the last years, shipping liners have been defined making huge efforts to overcome the prolonged recession of the global economy and the difficulties in the global shipping market. Their efforts like increasing the number of bigger vessels, merging and reentering to new alliances bring to the uncertain impact on the port industry. The current changes in the shipping industry have brought competition in port activities (Pando et al., 2005).

As the technology changes, the industry needs to change its views. As the seaports have become one of the main players in a global logistics chain (Robinson, 2002), port competition has run from competition among ports in competition to other transport networks. Unfortunately, the increasing demand for bringing more throughput to the port depends on how well port and TOC serve for shipping liners (Notteboom and Yap, 2012). For gaining a competitive advantage and serve the shipping liners, container ports should invest more in port facilities and equipment and use a favorable management system (Notteboom and Winkelmans, 2001; Cullinane and Song, 2002; Wang et al., 2005). Notteboom and Winkelmans (2001) argued the strategic scope of PAs should extend their operations than their classical facilitator operations. By changing their activities, modern seaports have become significant logistical and industrial centers (Notteboom and Yap, 2012). In a globalizing market with rapidly integrating and rationalized distribution systems, it is hardly surprising the significant structural and operational changes are taking space in ports, PAs and TOCs. A forceful effort in the improvements to the productivity in the cargo handling and providing the excellent maritime access gave a huge influence over the container ports on achieving the demand on the transportation of containers by shipping liners. Thus, the pace of capacity expansion should be adequate to meet the anticipated demand. Shipping companies also forwarded to become alliances with other transportation companies (Yoshida and Kim, 2004), and to enter major ports using joint ventures into TOCs (Lee, 2006), and to develop subsidiaries focused on terminal operations (Parola et al., 2013). These strategic alliances have brought the more complex relationship between the terminal merged shipping alliance companies and the port calls by seaports. From the carrier's view, a closer relationship to a TOC (Parola et al., 2013) and equity partnership to container terminal projects gives effective improvement to carrier's business networks (Parola et al., 2014).

The port management is challenging on a sustainable port development, following aspects: economic, technological, logistical, environmental, and community involvement (Bauk et al., 2015). As above-mentioned, shipping industry has currently experienced the overcapacity of vessels and large scale of vessels, well-integrated transport and logistics services with the greater market share of shipping lines generated through merging and alliance. These current changes have directly caused on another port player, like PA and TOC. They have brought into difficulties in capturing the demand of the main customers (Heaver et al., 2000). Furthermore, PAs and TOCs are seeking to develop the competitive position as a global port of call and adapt to the shifting market environment (Notteboom, 2017).

Furthermore, the shipping companies can bring down port-related charges and increase their economies of scale. This gives the container liner services become a higher quality of service with a high frequency of vessels in short transit time (Yoshida and Kim, 2004). Challenging in a great competition, ports have to take advantage of all the potential management. Developing an effective pricing strategy for the entire port community is one of the ways; the ports can meet the demands of the new situation (Pando et al. 2005).

Public-private partnership in port industry

By the introduction to new technologies in the port industry, the demand for the privatization of terminal operations was raised during the 1990s (Goss, 1990). Ports are currently moving toward formulas in which private initiative has a bigger role to play (Baird, 2002; Cullinane and Song, 2002; Cruz and Marques, 2012). Most of the PAs around the world has changed to transfer the operation of the container handling to private companies. For attaining the higher port performance and enabling the participation in the private sector in container port operations through Public-Private Partnerships (PPPs) and port concessions have become key considerations for the public authorities (UNCTAD, 2017).

World Bank (2001) proposed the four main governance models in the port industry. The main difference among these models is the possibility for public and private companies to manage port operations and activities. In the most adopted landlord model, PA is responsible for managing port areas with assuring traffic growth, social and economic wealth without directly performing any commercial activities (Meersman et al., 2009). The growth of privatization highlights the advance in two ways. The first way is to achieve more throughput between the origin and the destination areas, and second, to help the appropriate coordination of organizational activities as a commercial port (Pando et al., 2005).

At the same time, shipping companies have extended their interest in terminal operations by securing long-term concessions to the dedicated terminals. These developments resulted in the disappearance of independent local terminal management firms. The shipping companies manage their dedicated terminals to serve their own container carriers or their alliances' carriers.

Fewer services by giant shipping alliances lead to high competition among container ports, and among TOCs in ports to make as a port of call within a limited number of continental liner services (Notteboom, 2017). The TOCs are likewise scrambling to offer ship-owner service packages to grant their balance sheets. These kinds of issues enforce managers, commercial executives, charter-parties find the amount of decision makings related to price mechanisms (Notteboom, 2007).

Concession contracts

The well-established pricing policies of the PA are fundamental to distribute over a complex array of public and private stakeholders to face ongoing market challenges. Most of the PAs started to secure more ship calls (Notteboom, 2002). Among a variety of related studies on governing ports, PAs have mostly used two models for container terminal management until present. One type is some PAs invest in a terminal operating facility, and directly employs their stevedores and provides cargo handling services themselves. Another type is the PAs give the terminal and stevedore operation to the third parties. Both types of PA's main objectivity are to serve for multiple shipping liner customers. Each TOCs has the own group shipping companies for handling services (Slack and Fremont, 2005).

Bichou and Gray (2005) showed that port and terminal integration can cover all port-related plans and activities, process and procedures, as well as monitoring. Terminals in global supply chains are essential and their integration with shipping companies leads to higher performance and competitive advantages for the port (Notteboom and Rodrigue, 2005). In this way, port integration also should satisfy customers and achieve each PA's objective. Simply, ports should create and formulate new policies and plans which are best to adapt to the requirements of the changing shipping market environment. Greater cooperation through inter-ports and intra-ports will help to mitigate the negative impact on growing cost pressure in the container handling (UNCTAD, 2017).

Main challenge

Nowadays global maritime trade volume is going down because of the slowing economic recovery of major states and the slowing increase in emerging nations. The growth rate in 2015, 2016 and 2017 was among the lowest recorded by the maritime industry over the 2000-2017 period (exception to the Global Financial Crisis period in 2008-2009) (UNCTAD, 2017). As a result, for reducing costs through world economic decline, shipping companies have invested in large-scale container vessels, merged with other shipping companies (M&A), joined the maritime alliances. As being a superior position in a market, the alliance shipping companies did 'rate shopping' by requesting the TOCs to reduce the terminal handling charges (Choi, 2013).

Alliances and integration have made very powerful carrier groups that cause too much influence on a port performance and can leave its assets and the economic foundation of the port region stranded. The PA meets with port traffic risk as a function of the competitiveness (Heaver etc., 2000). The public PA tries to declare lowered rate for unloading containers to increase more throughput to the port. In the meantime, the declared terminal unloading fee causes competition between port operators, but the pre-shipment and cargo attraction competition between shipping companies caused by the excessive dumping of the terminal unloading charge. As a result, because the lower terminal handling charges of the public port extremely deteriorated the operational balance of the TOCs. The dumping of the terminal handling charges through the competition between TOCs causes of deteriorating the profitability of port operators and international competitiveness of ports.

In cases of market failure, unmatched incentives or unappropriated high operational costs, PA might initiate new partnerships or introduce new coordination mechanisms by improving the resource allocation (van der Horst and de Langen, 2008). The PAs need to improve conditions to TOCs by providing incentives and developing the proper plans with various infrastructures and facilities to operate. The adoption of the relevant technologies and solutions, port management, policy and regulatory processes in ports should be promoted. Thus, the collaboration between PA and TOC has become crucial (UNCTAD, 2017).

Currently, the PAs and the TOCs have got difficulties to catch demand from their customers due to change in a new environment, strategies, players and rules in the shipping industry. The problem addresses how to coordinate optimally between the public PA and TOCs on concession contract including in how to set equilibrium on the port tariff, and sharing risk from the uncertain demand. In another word, for being a successful partnership between these public and private companies, PA should design a contract by ensuring a clear distribution of roles and objectivities, managing the risk sharing system between parties appropriately, designing a clear policy framework, a judicial and regulatory system to properly manage the process.

2. Aim and Objectives

Port is a part of complex systems operating in an uncertain market environment. It is a central place where the integration of supply chain management meets in delivering value to shippers and other third-party logistics service providers. The interest of various port main players, i.e. PAs, TOCs, related service providers are sometimes in conflict. The PA can originate its revenues by managing, coordinating and exploiting its resources, operations, facilities, and labor of the port (Zahran et al, 2017), while TOCs can generate their revenues by operating services and marketing. In this study, using channel coordination models which require for the cooperation between PA and TOCs, an appropriate coordination model for PA and TOCs should be created in generating more joint profit. For this case, the controlling responsibility of PA is very important. The PA should play as a coordinator role in the port industry.

The foundations of the study were generated after a review of the port management literature and supply chain management literature. This study develops a port channel coordination model by taking the perspectives of different port stakeholders. The important task of this study is how to advance the issues which the PA has recognized. First, the objectivity of the public (PA) and private companies (TOC) is very different. The PA seeks how to attract more throughput, while the TOCs inquire how to get more profit from terminal operations. The PA seeks to minimize costs associated with goods handling and delays, but it has a limited control. It can determine port dues, but only has a partial control over the significant cost factor, and time such as ship-turnaround time and container handling rate (Meersman et al., 1997). Without coordination, the players determine their own decisions independently for maximizing own profits. The uncoordinated decisions bring out the double marginalization, which causes to "burden cost" for their customers (Tirole, 1988). The primary importance is that any form of coordination should satisfy a win-win situation between PA and TOCs and also it can increase the high efficiency and performance of both port players. With a well-balanced networking strategy, the PA should develop new resources and capabilities in close cooperation with other players with mutual interests (Notteboom and Winkelmans, 2001).

Second, many studies about concession contract between PA and TOC have been studied by different business decisions on pricing terminal leasing fees (Meersman et al., 1997), a period of the contract(Notteboom and Verhoven, 2009), risk sharing (Cruz and Marquez, 2012; Notteboom, 2007), as well as, profit sharing (Heaver, 2002).

Further studies dealing with complex aspects of coordination are applied in the port industry, related to on pricing depending on welfare (Strandenes and Marlow, 2000) and social opportunity cost (Button, 1979), a period of the contract (Notteboom and Verhoven, 2009), and maximizing throughput (Chen and Liu, 2015) and fee revenues (Saeed, 2009; Saeed and Larsson, 2010; Chen and Liu, 2012, 2014; Chen et al., 2017; Liu et al., 2018). However, these studies focus mostly on PA's goals. This study is concerned with the different objectivities and the coordination between port pricing and risk allocation models for PA and TOC's channel relationship.

The main aim of the research is to create a model on creating favorable cooperation on pricing and risk allocation between the PA and TOCs, compare them with other similar models and to calculate them numerically. Thus, the study explore how the proposed model can coordinate the cooperation between the PA and TOCs by improving overall efficiency.

This study promotes the knowledge on cooperative pricing and risk sharing between PA and TOC in these ways. First, the channel coordination studies will be reviewed in a literature and methodology parts. Second, the various models to enhance channel coordination in three disciplines, such as pricing the leasing fee and risk sharing will be proposed and compared. Third, the model will be compared through numerical calculations.

3. Significance

The scope of the study falls into the port marketing literature on the coordination of decentralized channels between PA and TOC in the port industry. The study makes a contribution as follows:

Since the channel coordination is researched deeply in marketing, supply chain, and operations management, there are no studies in the port industry. Other types of coordination model has studied in the port industry wherein PA and TOCs sign concession contracts on the terminal leasing fees only (Zang, 2008; De Borger et al., 2008; Saeed, 2009; Saeed and Larsson, 2010; Chen and Liu, 2014; Liu et al., 2018). The channel coordination models can help to find some good insights. In the example of Vancouver port, the first strategic goal is not port competitiveness, but contributing to local, regional and national economic growth.

Moreover, the port marketing is studied how to adapt directly the qualitative and non-pragmatic methods and models used in the marketing field into the port industry. The qualitative and non-pragmatic studies can give solutions in general without any detail calculations.

This study will explore to propose the complex model between PA and TOC corporation on joint profit such as how PA promote TOCs with discounts, and how they can share the risk which is come from the uncertain demand. In this way, this study will contribute to the port industry literature with accurate modeling and numerical analysis. As the port pricing and risk allocation issues in the landlord type of ports are very related, the study is very crucial for both PA and TOCs in the port.

4. Structure of the Thesis

The study paper is organized into five of chapters as follows:

In Chapter 2, the previous studies related to the port governance, port contract system and contract types will be reviewed. The studies on cooperative pricing, price promotion and risk sharing will be derived in this section. In Chapter 3, the theoretical background and model development will be given. The modelling on the cooperative pricing and pricing promotion as well as risk sharing will be proposed. In Chapter 4, the proposed models are calculated numerically and the interpretation of the results will be discussed. In last Chapter 6, the managerial implications, limitation and further study recommendation will be suggested.

Chapter 2. Literature review

1. Port economics

1. Port Governance

Privatization means the transfer of the ownership of the public assets or the provision services from the public sector to the private sector. Public-Private Partnership is an agreement which public sectors sign for a long-term contract with private-sector companies for the construction and management, or service provided by the private-sector company to the customers instead of a public sector (Grimsey and Lewis, 2002).

Most of the public PAs believe that enterprise-based port services will give them more flexible and efficient in the market and gives a better response to the market demand. De Monie (1995) defines the privatization scheme as "the form of commercialization of a PA in order to deflect the demand for much greater private sector involvement and safeguard."

Traditionally, ports have been managed by public authorities and now become an interesting business. By allowing the port services to the private companies, the port authorities can redefine their role (Notteboom and Winkelmans, 2001) and sustain the business in the competitive market (Van Niekerk, 2005), as well as PA bodies can encourage port operators to optimize more effectively the use of scarce resources (Notteboom, 2007). Brooks and Cullinane (2007) argue that there are mainly three drivers for the involvement of private companies in the port industry. They are the globalization of world commerce in web-based services and export and import industry, technological innovation, and last, but not least, changes in the public management philosophy, more become market-oriented (Notteboom and Winkelmans, 2001).

According to the procurement methods of Public-private partnership (PPP), they are divided into the build–transfer–operate (BTO) and build–transfer–lease (BTL) methods. Under the BTO agreement, a private consortium or company builds a facility, operates it for a specified period of time and transfer it back to the government at the end of the period. Contract duration is usually determined by the amount of time a concessionaire would realistically need to recoup its investment through user charges. Build–operate–transfer (BOT) and build–own–operate (BOO) procurement methods are also applicable as well. Other schemes such as build–lease–transfer (BLT), rehabilitate–operate–transfer (ROT), rehabilitate–own–operate (ROO), and rehabilitate–transfer–lease (RTL), are rarely used. Traditionally, port infrastructure facilities in Korea have been owned by the public government, and they widely use BTO and BTL methods (Kim et al., 2011).

World Bank (2001) distinguish the port/terminal ownership and operations into four groups:

a) public ownership and operation

b) public ownership and private operation and management

c) public ownership and private participation in superstructure installation and operations

d) private ownership and operations

World Bank (2007) divided into other four classifications of ports: a) public service port; b) toll port; c) landlord port; and d) private service port. The main difference among these models is the possibility for private and/or public companies to manage and organize port operations as well as to be directly involved in the port activities. Brooks and Cullinane (2007) define a public service port that PA assures the major functions, but a private service port that TOC owns and operates the port. In the toll port, all infrastructure system is owned, managed and maintained by the public authority, and a TOC pays a toll (fee) for the rent. In other words, private operators may only develop their own services without the possibility of having their own infrastructures.

Due to the classification developed by Baird (2000), the port governance of the container terminals in Korea is marked between the private and the private/public model.

Today, the typical institutional structure in the port sector is the landlord port model where a PA enters into concession agreements or public-private partnership schemes with a series of individual terminals.

In the landlord model, only the infrastructure is owned by the authority, and the superstructure and operations are managed by TOC. In this model, the public authority no longer has power to directly interfere, but the provision of port service is controlled by the private companies. Thus, while in public and in the tool ports, the public management body has an active role in the operations, in the landlord model the PA has only the planning and the management duty (Verhoeven, 2011).

Public seaports are interested in maximizing trade and economic prosperity to the regional community by serving more efficient trade (Heaver et al., 2000). As an example of Vancouver port, the first strategic goal is not port competitiveness, but contributing to local, regional and national economic growth. Today, the typical institutional structure in the port sector is the landlord port model. It is estimated that 85–90 percent of global ports are landlord ports, which account for about 65–70 percent of global container port throughput (Drewry Maritime Research, 2016).

A typical landlord is a model where a PA enters into concession agreements or public-private partnership schemes with a series of individual terminals. The public or State-owned body would own and manage the port area and infrastructure, including common facilities such as breakwater and entrance channels, utilities and inland access. It also acts as a landlord to tenants on long-term arrangements that invest in the superstructure and equipment, and carry out cargo handling (Drewry Maritime Research, 2016). Private partners acting on the basis of concessions is, on the other hand, responsible for terminal operations and related investments such as superstructure, equipment, cranes and wharf expansion. Concessions are generally awarded on a leasehold basis for 20 to 50 years and may include the rehabilitation or construction of infrastructure by the concessionaire. Concessions permit governments to retain ultimate ownership of port area and responsibility for licensing port operations and construction activities and to safeguard public interests.

The TOC organizational system also varies to horizontally and vertically due to integration. When TOCs control over facilities globally is called a horizontal expansion. However, when the terminal operations are controlled by the shipping lines is called vertical integration (Slack and Fremont, 2005).

Merging of global terminal operator groups by shipping companies within the port, PA gets difficulties into powerful and footloose players (Palliss et al., 2010). Theys and Notteboom (2010) point out that PA can tackle the problems in managing relations between the increasing power of shipping companies and TOCs through a well-organized concession contract. The PA can regulate port activities to reach social and economic objectives.

Baird (2000) divided port functions into the landlord, the operator, and the regulator. In the landlord model, the PA executes the landlord function, has responsibility for a part of the regulator function and leaves the operator function to the private companies. Verhoeven (2010) extended the basic functions of the landlord PA-based on Baird’s work by adding community manager functions and entrepreneurial functions. As a landlord, PA has to promote to develop port facilities and activities. Community managers invest in facilitating activities like technology, marketing and training (de Langen, 2008). In order to achieve their goals, i.e., strengthening the port complex in a competitive way, PAs depend on the performance of the individual port companies. PA has restricted involvement with commercial operations and services (Heaver et al., 2000). Commercial operations and services are performed by private-sector companies (Goss, 1990). In cases of market failure, unmatched incentives or unappropriated high operational costs, PA might initiate new partnerships or introduce new coordination mechanisms by improving the resource allocation (van der Horst and de Langen, 2008). The PA needs to improve conditions to TOCs by providing incentives and developing the proper plans with various infrastructures and facilities to operate. The adoption of the relevant technologies and solutions, port management, policy and regulatory processes in ports should be promoted. Thus, greater collaboration between PA and TOC has become crucial. (UNCTAD, 2017).

In a concession, the PA can indicate a minimum throughput to be guaranteed by the concessionaire. This encourages the lessee to market the facility and optimize the terminal and land usage. Failure to meet this obligation will incur a penalty to be paid by the TOC or the lease can be subject to termination. Throughput guarantees are considered a powerful governance tool, enabling more effective land management and land productivity. Performance targets incentivize better terminal utilization rates (Notteboom, 2007). Despite the similar organizational scheme, port governance models may differ from each other according to the applied location. Mediterranean Europe countries applied a landlord model as a more centralized governance framework in which PA acts with more limitation in operations dependent to the central government, while PA can act as a regulator and promoter in achieving the goals. But Northern Europe PAs are independent of the government from a strategic and financial viewpoint. They can act as facilitator and coordinator in the interactions among TOCs.

2. Contracts: Leasehold and Concession

The privately operated container terminals can be sub-divided into those where the land and infrastructure are owned by the operator and those whose core assets are owned by PA, with the operator granted exclusive use rights for a limited period of time. In other words, there are two types of concession are used in port governance: long-term lease and operating license. The concession agreement between a landlord PA and the private TOC can take the form of a long-term lease. Under the agreement, PA holds the ownership rights on facilities and receives lease payments annually from the TOC, while the TOC can expand the facilities during the contract period (Notteboom, 2007).

The majority of new port projects are based on build–operate–transfer concession agreements. Under such an agreement, a private consortium or company builds a facility, operates it for a specified period of time and returns it to the public sector at the end of that period. Contract duration is usually determined by the amount of time a concessionaire would realistically need to recoup its investment through user charges. The term "concession" covers the rights, obligations, and risks involved in collecting these fees, as well as in building and operating the facility. Such concessions are generally suited to projects involving considerable investment and operating content. The concession contract acts because of the government where the public authority allows to the third party the total or partial management of services, and PA just takes responsibility while other side takes the risk (European Commission, 2000).

The concession is used by the public body for regulating the private operators within the port. The concession negotiations help the PA to maximize the benefits of the terminal on the local territory (Ferrari et al., 2015). The PA's main goals of granting private operator company to control the port operations are to create more employment and to advance the trade in the country (de

Langen, 2008) by maximizing throughput volumes to the port. They are confined to investments in access and infrastructure and to concession policies with TOCs. These policies are important to the stability of establishments over time and to their efficiency. PAs have begun to express the strategic goals of maximizing value-added of the port as a whole. Other trends include an increasing importance assigned to accessibility and sustainability (Notteboom and Rodrigue, 2005).

Recent-updated studies discuss the major issues on concession contracts by mentioning how much concession contract affects for the port competitiveness (Meersman et al., 2009) in inter and intra-port competition (Kaselimi et al., 2011), how tender procedure can bring PA more efficient results to achieve their objectivities (Theys and Notteboom, 2010); the importance of new concession fee estimation methodology (Ferrari et al., 2013), as well as the lack of contract rules on renewal and contract duration (Notteboom and Verhoeven, 2009).

Ports have historically become the link between maritime and inland transport by unloading and loading containers from one transport to another one. They take on a significant part of the management and coordination of materials and data streams. Studying the competitiveness between Korean and Chinese container ports, Yeo et al. (2008) indicated that port competitiveness is determined by the port service, hinterland condition, availability, convenience, logistics cost, regional center, and connectivity. Efficiency, shipping frequency, appropriate infrastructure, better location, proper port charges, quick response to customers, transshipment and value-added services are most selected factors in ports (Tongzon, 2009; Murphy et al. 1992; Malchow, Kanafani 2004). Competing in maritime operations for transshipment cargo volumes may not be sustainable in the context of the new operating areas. Ports will need to reconsider their offerings by considering other services to customers, which would increase their revenues. However, as not existing more investment for facilities, port managers should focus on customer profitability and their marketing positioning in the mind of the targeted customers aiming to increase profits and benefits for the ports (Kotler and Keller, 2008). Creating a continuous value for the port community players, ports guarantee their reliability, continuous service and a good productivity level (Carbone and de Martino, 2003).

The public PA tries to minimize costs associated with goods handling and delays, but it has limited control. This is affected by maritime accessibility, but they have less influence on the more critical factors (Meersman et al., 1997). The main objective of TOCs is focused on the maximization of profits, so that long-term customer loyalty and an appropriate market share can contribute to attaining this goal. The port services of the TOCs are transporting the cargoes. They cannot sell major services to shippers directly. The TOCs' main customers are the shipping lines. In the long-run, how efficiently the TOC works in berth operations and serves for ship interfaces, so much they can find the opportunity successfully (Heaver, 2002).

Concession contracts mainly cover the payment, obligations, and risk allocation parts. In this study, we focus on concession payment and risk allocation parts between contracting parties.

3. Pricing Mechanism

A concession contract usually contains a payment by the terminal operator to the landlord port, consisting of a fixed annual fee (terminal lease) and a variable charge that depends on the volume of containers handled. The variable charge can be a fixed charge per container or a percentage charge on the terminal's revenue from container handling. It is also possible to have non-linearity in the variable part, making an average charge per container an increasing or decreasing function of the volume handled. The structure and level of charges embedded in the contract will influence the incentives and net revenue of the contract partners as well as the degree of risk sharing between them. Indirectly, the outcome of competition between terminals and, indirectly, ports, will also be influenced.

Differently from other industries, a port uses strategic pricing to achieve certain goals. The right prices on port services and cargo handling charges can lead a port to growth, while the wrong ones lead to inefficiency of the port operations. Higher prices may reduce a demand for port service, on the other hand, low prices may bring a port high demand, but operation costs of the port will be high (Haralambides, 2002).

Gardner (1977) argues port prices should be based on goods, not depend on ships and cargo. Button (1979) suggests that the port users should be charged the full marginal social opportunity cost of the resources which they use in the port. Arnold (1975) mentions that port tariffs come from a mix of pricing strategies to reflect the demand for the port services, market competition, and the cost of services provided. Talley (1994) assumes that the demand for port services is inelastic with respect to port prices, that is, two factors moves in opposite way.

UNCTAD (1995) created the 'cost, performance, value' (CPV) approach which allows port managers through tariffs to set the following plans: a) Cost-based tariffs can maximize the use of port services; b) performance-based tariffs can maximize the throughput and reduce congestion; c) value-based tariffs generate sufficient revenue to cover the port costs. And according to the CPV approach, the port bodies must not charge less than the port service cost, and not to charge more than the value received b the port users.

Petterson-Strandes and Marlow (2000) suggest that port prices should be differentiated on the basis of the quality of port services provided by the port operator related with time, punctuality of handling the cargo. Haralambides (2002) suggests that shipping companies are highly sensitive to port tariffs in order to make up for the operational loss of shipping carriers in when there is a decline in shipping freight rates due to intense competition in the container shipping industry. According to his studies, transshipment cargoes can be fluctuated more easily than O/D cargoes, thus increasing price elasticity of port demand.

Kim (2011) mentioned that when there is a significant gap between the container throughput growth rate of a specific port and the growth rate of a specific terminal due to unstable supply and demand which occurred from the irregular transshipment demand and the temporary oversupply, it leads to strengthening the market insecurity. Furthermore, the market insecurity that is the temporary imbalance in supply and demand, can increase due to the continuous development of container docks, high-sensitivity of shipping companies, strengthening cooperation and alliances among shipping companies which have a dominant position in the market.

As independent natures, the channel coordination participants choose decisions that maximize their own profits. In the lack of cooperation models, independent strategies of participants may lead to the chain inefficiency. In view of the importance of cooperative pricing on market demand, many scholars focus on how to model the pricing system under the environment of the supply chain.

Much of the literature on joint pricing-production and ordering decisions assumes depressed cost functions in different fields. Thomas (1970) generated a model on the joint pricing-production decision in a discrete-time setting. Deng and Yano (2000) extended that model by adding capacity constraints. Federgruen and Heching (1999) and Chan et al. (2000) focused on the pricing-production models with revenue functions. Weng (1995) and Chen et al. (2001) modeled a channel coordination with both pricing and production as well as ordering decisions. Weng (1995) modeled both a single manufacturer and multiple retailer systems and found that the channel coordination can be achieved with a quantity–discount policy.

The establishment of an appropriate legislative framework that guarantees and efficiency-oriented approach is one of the main challenges to port policymakers. Central governments adopt the role of coordinator in providing incentives to stimulate accountability and autonomy of PAs and in investment programs directed toward the provision of public goods.

2. Concession Contract Schemes

1. Fixed-fee contract

The fixed fee is the fixed royalty fee which the private company pays the public authority in the contracted period, such as annual, semi-annual periods. The lease to be paid to the PA takes the form of a fixed sum per square meter per year. The level of the lease amount is related to the initial preparation and construction costs, the location of the port and the type of activity. The fixed-fee system is straightforward and clear, easy to manage by the authority.

Before the contract is signed, PA gives a detailed information on all land concessions, a description of the port activity type, such as kind of cargo handling and port services, the current concessionaire and the fee per square meter per year. The highest fees will adjust to the most valuable land in the port area with large terminal space, advanced access to waterways and the hinterland location. In addition, the fixed fees can be different due to if the land is used as area or for buildings (Notteboom, 2007).

The fixed fee scheme is not only land rent fee per square, but also it can be calculated in other ways. Fixed fee equals the product of the market value of the leased facility and return on investment, as well as maintenance costs (Kil and Kim, 2016).

2. Unit-fee contract

Another kind of concession fee is unit fee contract. It is a variable royalty fee per ton or TEU (Notteboom, 2007). This kind of contract is used for profit-sharing conditions. As much as TOC attracts more cargoes, so much they can earn a profit, sharing with PA at the same time.

Kil and Kim (2016) describes that the unit fee scheme is calculated by setting the ratio of income share on excess quantity. In other words, unit fee equals to multiply the excess quantity, the amount of throughput, and the ratio of profit share.

3. Two-part tariff contract

In a two-part tariff the TOC pays to PA a fixed payment and plus a per-unit charge for each loaded container. In other words, two-part tariff contract is the combination of fixed-fee and unit-fee contracts in the negotiation.

Button (1979) suggest PA adopt two-part tariff schemes to price port tariffs. The two-part tariff is determined by the full marginal social opportunity cost of recourses used by shipping liner companies.

4. Foreign and Korean port contract schemes

Foreign countries contract system is classified into three groups: fixed fee, unit fee, and two-part tariffs. According to Kil and Kim (2016), most of the North American ports, Belgium, Thailand and Spain applied two-part tariff to their ports; Netherlands, Vietnam, Japan and Tacoma (USA) work on fixed fee scheme, and India and Philippines ports applied unit fee scheme to their terminal operating system (*See* Table 1).

The port authorities applied fixed fee scheme accounts fixed land rent fees (USA, Spain, Vietnam), the division between construction cost to expected income (USA (Tacoma), the Netherlands, Canada, Belgium, Thailand) or contract period (Japan), while the port authorities applied unit fee scheme considers the profit sharing (Thailand) and per TEU (India). The ports with two-part tariffs requests fixed land rents with minimum throughput condition to TOCs (Canada, Belgium, Thailand, USA).

In Korea, the current terminal pricing model is calculated due to the results of "The study on the calculation and the evaluation of the long-term rent model for Terminal Operating Company (TOC) system", presented by Ministry of Maritime Affairs and Fisheries in December 2003 (*See* Table 2). According to the rent calculation system, the total rental fee (Introduced in 2004 and was applying till present) consist of a) berth rental fee, b) yard and warehouse rental fee, c) road rental fee, d) handling facility and operating building rental fee.

There are few studies on Korea domestic TOC rent system. The existing studies suggest some changes to the calculation of rental system for domestic ports.

Lim and Lee (1999) assumed a study on the construction of the standard cost model to determine the appropriateness of the rent system in Busan Port.

Kim (2002) argues that terminal rent system should be based on its natural, physical and economic characteristics. As the size and facilities of each terminal are different, so the rent system for each port should be calculated in another way.

Table 1. Rent fee schemes in other countries

Country	Port	Rent fee system	Pricing standard		Rent period	Change of rent fee
			Fixed	Unit		
USA	Tacoma	Fixed fee	Construction cost and expected income	-	30 years	Increase rent fee in each 5-year
	New York	Two-part tariff	Land rent	Minimum throughput	-	-
	Auckland	Two-part tariff	Land rent	Income ratio	-	-
	LA	Two-part tariff	Land rent	Minimum throughput	30 years	-
Netherlands		Fixed fee	Construction cost and expected income	-	25 years	Change due to annual indexation
Vietnam		Fixed fee	Land rent	-	-	-
Japan		Fixed fee	Construction cost / contract period	-	10 years	Adjust to economic conditions, but not in principle
Canada	Vancouver	Two-part tariff	Construction cost / expected income	Minimum throughput	-	-
Belgium	Antwerp	Two-part tariff	Construction cost / expected income	Minimum throughput (penalty for less than minimum throughput)	-	Change due to inflation
Thailand		Two-part tariff	Construction cost / expected income, entrance fee	Minimum throughput	30 years	-
Philippines	Manila	Unit fee	-	Profit sharing	25 years	-
Spain	Algeciras	Two-part tariff	Land rent	Per container	-	-
India	Jawaharlal Nehru	Unit fee	-	Per TEU or profit sharing	-	-
	Tuticorin	Unit fee	-	Per TEU	-	-

Source: Kil and Kim (2016)

Table 2. Rental fee calculation method in Korea ports

Rental fee classification	Settled method	Statue of evidence
Main calculation method	- Total rent = (Berth + Yard + warehouse + road rent + handling facility rent & operating building rent) x annual rent increase rate - Annual rent increase rate – maximum producer price increase rate (2006-2010) for 5 years, the average for 3 years excluding the lowest price	
Berth	- Berth rent = Unit fee x handling capacity of terminal x ratio by item (processing performance) - Unit fee = ((Accreditation rate x adjustment factor – Wage distribution fee x 1.15 (miscellaneous expenses)) – labor cost x input personnel + indirect cost + management cost + margin)) / (Productivity per hour per hatch x number of hatch x Work time per day x number of working days annually x berth occupancy rate per port) - Handling capacity per terminal = productivity per hour per hatch x number of hatch x Work time per day x number of working days annually x berth occupancy rate per port x weight per terminal)	
Yard & Warehouse	- Yard (Package & Outgoing cargo): Apply the regulation on the use of port facilities and fees in commercial ports - Busan & Incheon ports: Area of use x 571 Won x per month x 12 months - Gwangyang & other ports: Area of use x 420 Won x per month x 12 months Warehouse (outgoing cargo): Apply the regulation on the use of port facilities and fees in commercial ports - Busan & Incheon ports: Area of use x 1288 Won x per month x 12 months - Gwangyang & other ports: Area of use x 1029 Won x per month x 12 months	The regulation on the port facilities and the fees in the commercial ports
Road	- Apply the 50% of yard fee	
Handling facilities & operating buildings	- Appraisal amount of the existing equipment/facilities x 50/100	National Property Act

Source: Ministry of Transport and Maritime Affairs, 2011.

Kil (2003) proposed a plan to revise the rent calculation system by reviewing the problems of Gwangyang port rent system. He suggested that rents should be negotiated by taking into consideration in both perspectives: PA investment recovery and TOC's operating balance maintenance.

Kil (2011) suggested a standardization method for calculating the rental fee system of Busan Port. However, the study is limited to apply it in practice.

Furthermore, Kil and Kim (2016) proposed the improvement scheme of the rent assessment system (2003-2014) of TOC. They considered the reform system using three criteria with standardization, simplification and fairness by applying the same ratio to all leased terminals with yards, warehouses and roads.

Government attempts to improve the TOC rental system several times, but they cannot change it yet because of TOCs worries about the sudden increase in rental level.

3. Risk Sharing Characteristics

The important part in the decision to give port ownership to private operators is the transfer of risk from the government to the private companies. The risk is defined, identified and measured, and either retained by the public or transferred to the private sector through the appropriate contract terms and payment mechanism. The risk can be allocated where it can be best managed. By 'best' managed means the party for whom it costs the least to prevent the risk from realizing. The public authorities cannot transfer the risks to the private sector associated with the statutory responsibilities to maintain services (OECD, 2012).

The conflict over the contract always occurs when the risk realizes. The private partners might also want to take on undefined risks. There should be clear methods in the contract by which risks can be apportioned when they materialize.

The main goal of the concession contract structure is to identify and create the formal relationship between PA and TOC for managing the port over given time. And one of the important aspects in the contract is risk assumption by the private sector.

Cruz and Marques (2012) identified the risk sharing of concession contracts in Portugal ports. Notteboom and Verhoeven (2010) acknowledged that the most often included clauses in the contracts between PA and TOCs in Europe relate to the throughput guarantee.

1. Risks types in concession contracts

There are different kind of classifications for the risks in the contracts. Grimsey and Lewis (2002) divided them into technical, construction, operating, revenue, financial, force majeure, regularity, environmental and project risks. And they divide into them into global and elemental risks. They assume that global risks are the risks out of the project, such as political, legal, commercial and environmental ones; and elemental risks are an association with construction, operation and financial parts of the projects.

Bing et al. (2005) classify into three levels: macro, meso and micro-level risks. Macro-level ones are associated with their origin beyond the system boundaries; meso-level ones are factors which related to the nature of the project, and micro-level risks are related to the relationships between the parties working in the projects.

Marques and Berg (2010) classify the risks into production, commercial and contextual risks. Production risks are planning, design, construction, environmental, expropriation, maintenance and major repairs, technological, operational and performance ones; commercial risks are demand, collection, capacity and competition risks; and contextual risks are financial, inflation, legal regulation, public contestation, unilateral changes and force majeure.

Cruz and Marques (2012) mentioned as the main risks in seaport concessions are planning and design, construction, permits, environmental, accessibility, operational, maintenance and repair, technological, demand, financial, legal, political and unilateral decisions as well as force majeure risks.

2. Risk allocation between PA and TOC

Concession contracts between PA and TOCs put some questions on how well to manage the risk. As we mentioned above chapters, TOCs are responsible for operating the terminal, while PA focuses on more possible volume of throughput to call. This generates some level of risk assumption between the parties.

Cruz and Marques (2012) allocated the risks between counterparties in five qualitative degrees, such as fully public, mostly public, equally distributed, mostly private and fully private. Planning and design, environmental, accessibility, political and contract unilateral changes and force majeure are analyzed totally and mostly by public authority sector; while construction and operational risks, as well as financial and legal risks, are assumed fully and mostly by private sector companies. The equally important risks between PA and TOCs are demand and market competition risks. Market competition is managed by two sectors using exclusive rights, while demand risk is difficult to control. The first reason is the PA and the TOC focus on high levels of traffic. TOC's revenue depends on the handled cargo, while PA's profit comes from terminal fees.

Concession fee is a mechanism of the transferring demand risk to PA partially. They can be divided into three types: flat rate, minimum-maximum rate, and shared revenue. In flat rate, all demand risk is handled by the TOC, while PA takes the fixed rent fee from TOC. The fixed rent is calculated according to the area and quay meters in the terminal. The minimum-maximum rate is the limit in the given rent. It may be changed according to the levels of traffic. The shared revenue is the same as two-part tariff including a fixed and variable component of the risk.

One of the main questions between two counter-parties is how to cover the costs incurred during the contract period. Notteboom (2007) forwards two policy suggestions for port concessions. In case of subsidized port infrastructure, PA becomes full-cost recovery with concession fees. PA should minimize the distortions in resource use, continues giving incentives for efficient use of port infrastructure and be implemented in a transparent manner by fixing concession fees. And in a second way, PA might lease out land at a price below the land value hoping TOC brings more high value-adding logistics and industrial activities to the port.

Chapter 3. Theoretical Background and Model Development

1. Theoretical Background

An oligopoly is a form of the market structure where an industry is dominated by a small number of sellers. The oligopolistic companies can reduce competition and set higher prices for customers. The decision of a firm influence and at the same time are influenced by the decisions of other firms.

Oligopoly has different characteristics than monopoly and perfect competition market forms. In the oligopolistic market, the number of the companies which can affect the market price is two or more; and the market share of an individual firm is large enough. Since the fluctuations in the supply of an individual firms affect the total supply of the market, they change the market price. The barriers to entry into the market are high.

The main characteristic in oligopoly market wherein the number of firms is small is a consideration to the responses of other firms when they make decisions on price, quantity, quality, and advertisement. Because there is a mutual dependence on each other among the firms. Individual firms take strategic actions in consideration of the other firm's responses, and the market performance follows the strategic behavior of the firm. In other words, it depends on how the other firm will respond to the expected profit if the oligopolistic firm wants to raise the price. However, in a perfectly competitive market, the supply capacity of the individual firm is limited and the market prices are given, so there is no need to consider the responses of the rest of the firms in determining the that maximizing profits. In a pure monopoly where there is no competing party, so there is no need to consider the reaction of the other firms in setting the price or production.

Since the number of the firms are too small, different kind of strategic games may arise in the oligopoly market.

There is two kind of games in oligopoly due to the cooperation or not between the firms: non-cooperative and cooperative oligopoly. In a case of non-cooperative oligopoly, there is no collusion between the firms in price, production quantity, quality, investment, advertising, R&D and so on., and each firm makes decisions independently. In contrast, firms make joint decisions through the collusion by maintaining the independence legally in the cooperative oligopoly. Corporate strategy is very complex and broad in all the activities of the firm.

1. Bertrand model

The Bertrand model, formulated in 1883 by Joseph Louis Francois Bertrand (1822-1900), describes interactions among firms that set prices and their customers that choose quantities at the prices set. Bertrand model is used in strategic pricing choice more than quantity one.

In Bertrand model, there are two firms which sell homogeneous products and have identical constant marginal costs (mc). Both of them set the price continuously to maximize their own profits. The firm which sells at lower price calls all market demand *Q(p)*. At equal prices, the market divides into two, like α_1 and $\alpha_1 = 1 - \alpha_1$; then, the firm i faces demand

$$Q_i(p_i) = \begin{cases} Q(p_i) \text{ if } p_i < p_j, \\ \alpha_i Q(p_i) \text{ if } p_i = p_j, \\ 0 \text{ if } p_i > p_j. \end{cases}$$

In this model, the only strategy equilibrium is when both firms' price setting equals their marginal costs, p=c. Thus, firms do not enjoy any market power. If two firms set the same price, the more efficient firm gets all the demand.

In the equilibrium of the Bertrand game with asymmetric costs, both firms use weakly dominated strategies: setting a higher price cannot make the firm worse off. A firm faces a competitor of unknown costs; it appears that the firm no longer has an incentive to set price equal to marginal costs. Firms set price above marginal costs and make strictly positive expected profits in equilibrium. More firms in the industry lead to lower price-cost margins, higher output, and lower profits.

A profit-maximizing retailer sets the retail price where marginal cost equals marginal revenue. A reduction in the wholesale price reduces the retailer's marginal cost, and therefore it must reduce its price to reduce its marginal revenue by the same amount (Lee and Staelin, 1997).

2. Cournot model

Cournot model, one of most classic models of the oligopoly market is proposed by Cournot in 1838. There are some assumptions in the model: First, there is no collusion of the price or production quantity in the market. Second, the products on the market are homogeneous. Third, product quantity is a strategic variable among oligopolistic firms. Fourth, the supply quantity among firms is constant. Fifth, there is no limit to the supply quantity for the firms. The individual firm can change its supply quantity limitless due to the change of the supply quantity of the other firm.

In order to the Cournot duopoly market to be balanced, the profit maximization conditions of the two companies must be satisfied at the same time.

$$MR_1 = P + Q_1 \frac{dP}{dQ} \times \frac{dQ}{dQ_1} = MC$$

$$MR_2 = P + Q_2 \frac{dP}{dQ} \times \frac{dQ}{dQ_2} = MC$$

Here, $\frac{dQ}{dQ_i}$ is the effect of the change in supply quantity of firm i on total supply quantity. If there is no information on how much supply quantity of the firm effect to the total supply quantity, then conjectural variation will be equal to 0 (CV=0) and the effect change will be equal to 1 ($\frac{dQ}{dQ_i} = 1$). In the former equilibrium model above, the response function $Q_1 = R_1(Q_2)$ of firm one is derived. The equation shows how Q_1 response when Q_2 increases. The equilibrium is the intersection of the both firm's reaction functions which show how one firm reacts to the other firm's quantity choice.

In the Cournot equilibrium, the quantity choice between two firms meets the equilibrium point. If the firms' cost conditions are same, then the profits of them are determined at the same time. By reaching the equilibrium point, two firms decrease the quantity by using collusion and both can raise their profits at the same time. This collusion may bring a favorable result for both firms. At the same time, common knowledge (information) between them is also very important.

3. Stackelberg model

The Stackelberg model, proposed in 1934 by German economist Heinrich Freiherr von Stackelberg, is the extension model of Cournot model. In Stackelberg model, the firm knows the reaction curve of another firm. In another word, the second firm doesn't know the reaction curve of the first firm, while the first firm knows the reaction curve of the second firm. The leader moves first and makes its decision taking into consideration the reaction of the follower. The first firm determines the output that maximizes its profits, accounting for the reaction function of the second firm. Then the second firm determines its production quantity depends on the first firm's choice as given. In this case, the first firm will be a leader, and the second one will be a follower. Thus, the leader moves first and then the follower firm moves sequentially. The leader may expect the follower to conform to the choices given by his reaction function. At a Stackelberg equilibrium, both firms optimize given their beliefs and the firms' beliefs are self-fulfilled for these equilibrium choices (Tirole, 1988).

The Stackelberg oligopoly equilibrium model may be conceived as a subgame perfect Nash Equilibrium of a two-stage game, where each player moves in a prescribed order (Fudenberg and Tirole 1991). One unique feature of the Stackelberg duopoly model when firms compete on quantity is the following: under both assumptions of linear market demand and constant equal marginal costs, the leader always achieves a higher payment than the follower.

4. Collusion model

The channel coordination's main goal is to improve the performance optimization by connecting the different objectives of multiple partners in the industry. In a channel coordination, the partners should improve the performance by approaching to the optimal plan. Its theoretical foundations are found in the contract theory. In a centralized coordination, there is a unique decision maker, and this gives more efficiency in the decision-making process. However, the decentralized decision making leads to a dilemma situation in a double marginalization (Eskandari et al., 2010) and bullwhip effect (He et al., 2009). The objective of channel coordination can be maximizing profit only or involve other considerations as well (Cui et al., 2007). A channel coordination mechanism could help the independent players to manage their dependencies in order to achieve coordination and optimize the performance.

Last decades, many contracting mechanisms have modeled in various situations and industries.

The channel can be a monopolistic case (Jeuland and Shugan, 2008) or contain one or more competitive cases (Ingene and Parry, 2000; Geylani et al., 2007). The relationships among channel players can be informal and simplistic or strict and complex (Lal, 1990). The channel players can be perfectly rational or opposite due to their behavior (Ho and Zhang (2008)). From the viewpoint of game theory, the models can take cooperative or non-cooperative approaches, the cooperative approach studies how the players form the coalitions on the strategic level of networking (Choi etc., 2018).

In last decades, most of the PAs have transferred to meet the need of fast-growing international trade volume and the competitive environment around it. Some of the PAs shifted from owners and operators to landlords of ports. These landlords of ports lease lands and facilities of the port to private sectors through a concession contract. These contracts consider how TOCs pay for the rented lands and capital facilities of the port. Whether the signed contract brings more benefit for ports and private TOCs depends on the calculation and the design of the corresponding concession contracts. Since the channel coordination model is favorable in characterizing interactions among the players, the study attempts to model the concession contract between the PA and TOCs through the channel coordination model.

Studies related to the application of channel coordination to the port industry are rare. Anderson et al. (2008) modeled a game-theoretic best response framework to know how competing ports will respond to the development at the port and if the port can sustain its market share by creating additional capacity. And they applied the model to the competition between Busan and Shanghai Ports and developed a pricing game-based analysis of both ports' development policies focused on the development game given the projected prices.

Zhang (2008) focused on the quantity of competition and price of competition between ports dealing with the interaction between hinterland conditions and port competition.

De Borger et al. (2008) analyzed the relationship between the pricing behavior of the ports and the optimal investment policies, as well as the hinterland capacity. They used the two-staged frameworks in both capacities and prices. They assumed the capacity decisions are done by the government, while the pricing decisions were done by the private operators. They concluded that the profit-maximizing ports adopted to hinterland congestion; the investment in port capacity reduces prices and congestion at both ports, while it increases the hinterland congestion in the region; the increased hinterland congestion minimizes the direct benefits of extra port activities; and lastly, generating the congestion tolls on the hinterland roads increases both port and hinterland capacity investments.

There are few coordination researches related to the terminal rent system. These studies were limited in practice.

Saeed and Larsen (2010) use a Bertrand game to analyze how TOCs' pricing and PA's profits in Pakistan vary with different concession contracts. Their simulations show that optimal concession contracts should have high unit fees and low annual rents.

Fu and Zhang (2010) and Zhang et al. (2010) inspect sharing concession revenues between airports and airlines and find that the sharing design can bring higher social welfare but may cause more serious competition among airlines.

Chen and Liu (2014) find that the two-part tariff or the unit-fee contract is the best for a fee revenue maximizing PA, while Chen and Liu (2015) discover that the fixed-fee contract is optimal for a throughput-maximizing PA.

Liu et al. (2018) derive the optimal concession contracts by considering minimum throughput requirements.

Table 3. Related literature on the modeling of concession contracts between PA and TOC

Authors	Methodologies	Goals	Suggested contracts
Button (1979)		PA charges a fee equal to the marginal social opportunity cost	Two-part tariff
Strandenes and Marlow (2000)		PA charges a fee depending on welfare	Two-part tariff
Saeed and Larsen (2010)	Bertrand game	Maximize profit of PA	Two-part tariff
Chen and Liu (2014)	Cournot mode, Subgame perfect Nash equilibria	PA maximizes fee revenue from TOC	Two-part tariff + unit-fee contract
Chen and Liu (2015)	Subgame perfect Nash equilibria	PA maximizes container throughput	Fixed-fee contract
Chen et al. (2017)	Subgame perfect Nash equilibria	PA maximizes fee revenue from TOC	Two-part tariff + unit-fee contract
Liu et al. (2018)	Subgame perfect Nash equilibria	PA maximizes fee revenue under minimum throughput requirement	Unit-fee contract

In the previous studies, most of the studies have conducted by the government and port authorities. They put the aim of how PA can gain more profit by changing the strategic goals. And they preferred two-part tariff more when PA seeks to profit from charging a fee on marginal social opportunity cost and welfare; two-part tariff and fee contract by increasing concession fees; unit fee contract by increasing concession fee under minimum throughput requirement; and the fixed-fee contract by increasing the container throughput to the terminal.

2. Model development

This chapter focuses on modeling the joint profit equilibrium for the two-part tariff, unit fee, fixed fee and mixed fee contract schemes in different models, and compare them on the mathematic way. Thus, the chapter consists of mainly Coordination through modeling the joint profit on leasing contract and profit/risk sharing between PA and TOCs, as following ways:

1. Coordination through Port Contract Schemes
2. Coordination through Port Profit and Risk Sharing

Each section consists of model assumption, modeling on four contract schemes, equilibrium comparison among the schemes. In the beginning sections, each TOCs and PA's decentralized profit maximization, and later their joint profit maximization are modeled, and then each of them are compared numerically with graphics in case of changes of cost (c) and service differentiation level (b).

The problem considered in the research paper is of a single PA who earns its profit from berth rents by leasing to two different TOCs. The PA makes decisions on the how to increase rent fees and increase more throughput, while the TOCs make decisions on how to increase their profit by increasing port tariffs. The study will examine the effect of various parameters on the optimal pricing and efforts on joint profit increasing by the channel players. It may be in the interest of both the PA and TOCs to contribute on joint profit generation.

The research model is created for the one PA and two TOCs condition. The study puts an assumption that there are one PA and two TOCs, which provide differentiated services, with different amounts of cranes and gantries to handle containers, distinct terminal locations, or dissimilar facilities to store cargoes. Here, the market demand functions faced by TOC_1 and TOC_2 are assumed to be respectively

$$p_1 = 1 - q_1 - bq_2$$
$$p_2 = 1 - q_2 - bq_1$$

where p_i is the price of unit cargo (TEU) charged by TOC_i, and q_i is the amount of cargo handled by TOC_i; $i = 1,2$. Parameter $b \in (0, 1)$ represents the service differentiation level. The larger is b, the lower is the differentiation degree of the services.

Uploading and unloading containers will incur service costs to TOCs, such as wages of the labor and rents for gantries and other equipment. Let

$$C_i(q_i) = c_i q_i, i = 1,2.$$

$c_i q_i$ is the cost function of operator *i* to handle cargo amount q_i , where ci with $0 < c_i < 1$ is operator i's marginal service cost, i = 1,2.

The expansion of the cost function will be:

$$C_1(q_1) = c_1 q_1, \quad 0 < c_1 < 1$$
$$C_2(q_2) = c_2 q_2, \quad 0 < c_2 < 1$$
$$c_1 = c_2 = c$$

Differently from Chen and Liu (2014), who assume $c_1 < c_2$ as TOC_1 is more cost-efficient than TOC_2, it is assumed the both TOCs cost is same, so it gives us to model the formula easier the model further.

In addition to service costs, TOCs should pay fees to rent terminals from the PA. It is presumed that the PA can offer two-part tariff, unit-fee, or fixed-fee contract to the TOCs.

- *Fixed-fee scheme*: the PA charges TOCs a fixed fee, $f(f > 0)$, irrelevant to the cargo amounts handled.

- *Unit-fee scheme*: the PA charges TOCs a unit fee, r, for per unit cargo loading.
- *Two-part tariff scheme*: the PA collects both a fixed and a unit fees, (r, f) from the operators.
- *Mixed fee scheme*: the PA charges one TOC a fixed fee and another one a unit fee.

Because of identical concession, the PA has rent fee revenue from both TOCs as follows:

- *Fixed-fee scheme*: f
- *Unit-fee scheme*: $r(q_1 + q_2)$
- *Two-part tariff scheme*: $2f + (q_1 + q_2)$
- *Mixed fee scheme*: $r(q_1 + q_2)$ or f

The game proceeds as follows:

First, the PA announces a fee scheme to maximize her goal; and second, given the fee scheme by the PA, both TOCs choose simultaneously and independently their optimal cargo amounts to maximize their profits. Because this is a complete information game, the subgame perfect Nash equilibrium(SPNE) can be obtained through backward induction.

Both TOCs' main goal is to maximize their profits. The model would vary by contract types, such as concession fee. So, each TOC's profit function will be

$$max\ \pi_1 = (1 - q_1 - bq_2)q_1 - (c + r)q_1 - f = p_1q_1 - (c+r)q_1 - f$$

$$max\ \pi_2 = (1 - q_2 - bq_1)q_2 - (c + r)q_2 - f = p_2q_2 - (c+r)q_2 - f$$

On the other hand, the PA can play as a public operator entity pursuing joint profit maximization. So, the joint profit maximization occurs by the combination of PA, TOC_1 and TOC_2's profit maximizations.

$$\max \Pi_j = \pi_p + \pi_1 + \pi_2$$
$$s.t. \pi_p = 2f + r(q_1 + q_2)$$

The optimal model for the joint profit are generated in the next coming subsections.

1. Terminal operators' optimal behaviors under three schemes

Given each of the contract scheme, the associated optimal behaviors of TOCs are derived in the following subsections.

1-1. Under two-part tariff scheme

When two-part tariff scheme *(r, f)* is adopted, the PA will collect unit-fee $r > 0$ per cargo for the amounts handled by TOCs, and a fixed-fee $f > 0$, *when* operators choose optimal quantities (q_1^*, q_2^*) to solve the following problems. So, each TOC's profit function will be

$$max\ \pi_1 = (1 - q_1 - bq_2)q_1 - (c + r)q_1 - f = p_1 q_1 - (c+r)q_1 - f$$
$$max\ \pi_2 = (1 - q_2 - bq_1)q_2 - (c_2 + r)q_2 - f = p_2 q_2 - (c+r)q_2 - f$$

The Kuhn-Tucker or first-order conditions for (q_1^*, q_2^*) are

$$\frac{\partial \pi_1}{\partial q_1} = 1 - 2q_1 - bq_2 - (c + r) = 0$$
$$\frac{\partial \pi_2}{\partial q_2} = 1 - 2q_2 - bq_1 - (c + r) = 0$$

By solving the simultaneous equation, it is obtained in the following ways:

$$q_1^* = \frac{1-(c+r)}{2+b} \quad \text{and} \quad q_2^* = \frac{1-(c+r)}{2+b},\ q_1^* = q_2^* = q^*$$

$$p_1^* = \frac{1+(1+b)(c+r)}{2+b} \quad \text{and} \quad p_1^* = \frac{1+(1+b)(c+r)}{2+b},\ p_1^* = p_2^* = p^*$$

To have nonnegative equilibrium cargo amounts for both TOCs, it is assumed TOC's marginal service cost and PA unit-fee cannot be too large so that both operators will handle nonnegative cargo amounts. If PA charges unit-fee too high, then one of the TOC may exit the market. By above results, TOCs' profit will be:

$$\pi_1^* = (q_1^*)^2 - f$$

$$\pi_2^* = (q_2^*)^2 - f$$

1-2. Under unit-fee scheme

Given unit fee r, operators choose optimal quantities (q_1^u, q_2^u) to solve the following problems. By letting *f=0* at (*r, f*), a unit-fee scheme is given, and operator i's profit function becomes π_i with *f=0,*

$$max\ \pi_1 = (1 - q_1 - bq_2)q_1 - (c + r)q_1 = p_1q_1 - (c_1 + r)q_1$$

$$max\ \pi_2 = (1 - q_2 - bq_1)q_2 - (c + r)q_2 = p_2q_2 - (c + r)q_2$$

The first order conditions for (q_1^u, q_2^u) are

$$\frac{\partial \pi_1}{\partial q_1} = 1 - 2q_1 - bq_2 - (c + r) = 0$$

$$\frac{\partial \pi_2}{\partial q_2} = 1 - 2q_2 - bq_1 - (c + r) = 0$$

By solving the simultaneous equation, it is obtained as follows:

$$q_1^u = \frac{1-(c+r)}{2+b} \quad \text{and} \quad q_2^u = \frac{1-(c+r)}{2+b}, \quad q_1^u = q_2^u = q^u$$

$$p_1^u = \frac{1+(1+b)(c+r)}{2+b} \quad \text{and} \quad p_1^u = \frac{1+(1+b)(c+r)}{2+b}, \quad p_1^u = p_2^u = p^u$$

By above results, both TOCs' profit is

$$\pi_1^u = (q_1^u)^2$$

$$\pi_2^u = (q_2^u)^2$$

As a result, it is similar to above that under two-part tariff scheme.

$$q_1^* = q_2^* = q_1^u = q_2^u,$$
$$p_1^* = p_2^* = p_1^u = p_2^u.$$

1-3. Under fixed-fee scheme

Given fixed fee *f*, operators choose optimal quantities (q_1^f, q_2^f) to solve the following problems. By letting *r=0* at (*r, f*), a fixed-fee scheme and each TOC's profit function becomes π_i with *r=0*.

$$max\ \pi_1 = (1 - q_1 - bq_2)q_1 - cq_1 - f = p_1 q_1 - cq_1 - f$$
$$max\ \pi_2 = (1 - q_2 - bq_1)q_2 - cq_2 - f = p_2 q_2 - cq_2 - f$$

The first order conditions for (q_1^f, q_2^f) are

$$\frac{\partial \pi_1}{\partial q_1} = 1 - 2q_1 - bq_2 - c = 0$$
$$\frac{\partial \pi_2}{\partial q_2} = 1 - 2q_2 - bq_1 - c = 0$$

By solving the simultaneous equation, it is obtained as follows:

$$q_1^f = \frac{1-c}{2+b} \quad \text{and} \quad q_2^f = \frac{1-c}{2+b}, \quad q_1^f = q_2^f = q^f$$
$$p_1^f = \frac{1+(1+b)c}{2+b} \quad \text{and} \quad p_1^f = \frac{1+(1+b)c}{2+b}, \quad p_1^f = p_2^f = p^f$$

By above results, both TOCs' profit is

$$\pi_1^f = (q_1^f)^2 - f$$
$$\pi_2^f = (q_2^f)^2 - f$$

1-4. Under mixed-fee scheme

Given fixed fee f and r, operator 1 choose optimal quantity q_1^m, and operator 2 choose optimal quantity q_2^m. Thus operators choose (q_1^m, q_2^m) to solve the following problems.

$$\max \pi_1 = [1 - q_1 - bq_2]q_1 - cq_1 - f$$
$$\max \pi_2 = [1 - q_2 - bq_1]q_2 - (c + r)q_2$$

The first order conditions for (q_1^f, q_2^f) are

$$\frac{\partial \pi_1}{\partial q_1} = 1 - 2q_1 - bq_2 - c = 0$$
$$\frac{\partial \pi_2}{\partial q_2} = 1 - 2q_2 - bq_1 - (c + r) = 0$$

By solving the simultaneous equation, we obtain as follows:

$$q_1^m = \frac{1-c}{2+b} - \frac{2r}{4-b^2} \quad \text{and} \quad q_2^m = \frac{1-c}{2+b} + \frac{br}{4-b^2},$$

$$p_1^m = \frac{1+(1+b)c}{2+b} + \frac{2-b^2}{4-b^2}r \quad \text{and} \quad p_1^m = \frac{1+(1+b)c}{2+b} + \frac{br}{4-b^2}.$$

By above results, both TOCs' profit is

$$\pi_1^m = (q_1^m)^2 - f$$

$$\pi_2^m = (q_2^m)^2$$

2. Port authority's optimal behaviors under four schemes

After modeling the basic profit function of TOCs, PA's profit maximization is discussed further. In the following subsections, PA's optimal behaviors are described and her equilibrium revenues in different schemes are compared. The optimal fee scheme is given due to the different types of PA's goal. The current studies (Strandenes and Marlow, 2000; Saeed and Larsen, 2010; Chen and Liu, 2014; Chen and Liu, 2015; Chen et al., 2017; Liu et al., 2018) put the objectivities how to maximize the PA's profit; however, this research studies and models how to maximize the joint profit between PA and TOCs. This is the first attempt on this field.

There are two objectives of the study: one is to find optimal fee scheme(s) with maximum joint profit, which is covered with the previous studies (Chen and Liu, 2014; Liu et al. 2018); and second is to model the joint profit maximization, which gives the port marketing sense.

2-1. Without coordination equations

2-1-1. Under two-part tariff scheme

In this section, the profit maximization schemes are modeled on PA viewpoint. When a two-part tariff contract is offered, PA's fee revenue equals:

$$\pi_p = 2f + r(q_1 + q_2)$$

where q is the cargo amount handled by each TOC.

Given $(q_1^*, q_2^*, \pi_1^*, \pi_2^*)$, the PA will choose (r^*, f^*) to solve the problem of

$$\max \pi_p = 2f + r(q_1^* + q_2^*)$$

The first order conditions for (r^*, f^*) are

$$\frac{\partial \pi_p}{\partial r} = (q_1^* + q_2^*) - \frac{2}{2+b} r = 0$$

$$\frac{\partial \pi_p}{\partial f} = 2$$

The value of $\frac{\partial \pi_p}{\partial f}$ is always higher than 0, so that, as much as the value of f increases, so much as the profit will increase. If the TOC's profit is less than zero, the negotiation itself cannot be signed. So, the following conditions should be satisfied:

$$\pi_1^* = (q_1^*)^2 - f \geq 0$$

$$\pi_2^* = (q_2^*)^2 - f \geq 0$$

As $q_1^* = q_2^* = q^*$, the condition will not be changed. Therefore, the maximization of PA's profit for (r^*, f^*) will be as follows:

$$r^* = \frac{1-c}{2}$$

$$f^* = \frac{1}{4}\left(\frac{1-c}{2+b}\right)^2$$

$$0 \le f^* \le (q^*)^2 = \left(\frac{1-c}{2(2+b)}\right)^2 = \frac{1}{4}\left(\frac{1-c}{2+b}\right)^2$$

The profit functions in two-part tariff scheme is considered for the PA:

$$\pi_p^* = 2r^*q^* + 2(q^*)^2 = 2q^*(r^* + q^*)$$

$$\pi_p^* = \frac{3+b}{2}\left(\frac{1-c}{2+b}\right)^2.$$

2-1-2. Under unit-fee scheme

If f=0, PA's fee revenue from offering a unit-fee contract is

$$r(q_1+q_2)$$

Given $(q_1^u, q_2^u, \pi_1^u, \pi_2^u)$, the PA will choose r^u to solve the problem of

$$\max \pi_p = r(q_1^u + q_2^u)$$

The first order condition for r^u is

$$\frac{\partial \pi_p}{\partial r} = (q_1^u + q_2^u) - \frac{2}{2+b} r = 0$$

Therefore, when f=0, the maximization of PA's profit for r^u will be as follows:

$$r^u = \frac{1-c}{2}$$

$$f^u = 0$$

$$\pi_p^u = r^u(q_1^u + q_2^u)$$

Because of $q_1^* = q_1^u$, $q_2^* = q_2^u$ and $r^* = r^u$, $r^u(q_1^u + q_2^u)$ is equal to $r^*(q_1^* + q_2^*)$.

So that, the profit functions of unit fee contract scheme are considered for the PA:

$$\pi_p^u = r^u(q_1^u + q_2^u) = 2r^* q^*$$

$$\pi_p^u = \frac{2+b}{2}\left(\frac{1-c}{2+b}\right)^2$$

2-1-3. Fixed-fee scheme

When $r=0$, PA's fee revenue from offering a fixed-fee contract is

$$2f$$

Given $(q_1^f, q_2^f, \pi_1^f, \pi_2^f)$, the PA will choose f^f to solve the problem of

$$\max \pi_p = 2f$$

The first order condition for f^f is

$$\frac{\partial \pi_p}{\partial f} = 2$$

The value of $\frac{\partial \pi_p}{\partial f}$ is always higher than 0, so that, as much as the value of f increases, so much as the profit will increase. However, if the TOC's profit is less than zero, the negotiation itself cannot be signed. So, the following conditions should be maintained:

$$\pi_1^* = (q_1^*)^2 - f \geq 0$$
$$\pi_2^* = (q_2^*)^2 - f \geq 0$$

Because of $q_1^f = q_2^f = q^f$, f is equal to q^f, when $r = 0$. Therefore, the maximization of PA's profit for f^f will be as follows:

$$f^f = (q^f)^2, \quad 0 \leq f^f \leq (q^f)^2 = \left(\frac{1-c}{2+b}\right)^2$$
$$r^f = 0, \quad f^f = \left(\frac{1-c}{2+b}\right)^2$$

The profit functions in fixed contract scheme is considered for the PA:

$$\pi_p^f = 2(q^f)^2$$
$$\pi_p^f = 2\left(\frac{1-c}{2+b}\right)^2$$

2-1-4. Mixed-fee scheme

Given $(q_1^m, q_2^m, \pi_1^m, \pi_2^m)$, the PA will choose (r^m, f^m) to solve the problem of

$$\max \pi_p = f + r q_2^m$$

$$\frac{\partial \pi_p}{\partial r} = q_2^m - \frac{2}{4-b^2} r = 0$$

$$\frac{\partial \pi_p}{\partial f} = 1$$

The value of $\frac{\partial \pi_p}{\partial f}$ is always higher than 0, so that, as much as the value of f increases, so much as the profit will increase. However, if the TOC's profit is less than zero, the negotiation itself cannot be signed. So, the following conditions should be maintained:

$$\pi_1^m = (q_1^m)^2 - f \geq 0$$

$$f^m = (q_1^m)^2$$

Therefore, the maximization of PA's profit for (r^m, f^m) will be as follows:

$$r^m = 0$$

$$f^m = \left(\frac{1-c}{2+b}\right)^2$$

The profit functions in mixed contract scheme is considered for the PA:

$$\pi_p^m = (q_1^m)^2 + r^m q_2^m$$

$$\pi_p^m = \left(\frac{1-c}{2+b}\right)^2$$

2-2. With coordination

2-2-1. Under two-part tariff scheme

Given $(q_1^*, q_2^*, \pi_1^*, \pi_2^*)$, the PA will choose (r^*, f^*) to solve the problem of

$$\max \Pi_j = \pi_p + \pi_1^* + \pi_2^*$$
$$\Pi_j = 2f + r(q_1^* + q_2^*) + (q_1^*)^2 - f + (q_2^*)^2 - f$$
$$\Pi_j = 2\left[rq^* + (q^*)^2\right]$$

The first order condition for (r^*, f^*) is

$$\frac{\partial \Pi_j}{\partial r} = b(1-c) - 2(1+b)r = 0$$
$$\frac{\partial \Pi_j}{\partial f} = 0$$

If the TOC's profit is less than zero, the negotiation itself cannot be signed. So, the following conditions should be maintained:

$$\pi_1^* = (q_1^*)^2 - f \geq 0 \text{ and } \pi_2^* = (q_2^*)^2 - f \geq 0$$

Because of $q_1^* = q_2^* = q^*$, f is equal to q^*. always has to be a positive value due to the conditions of b and c. Therefore, the maximization of PA's profit for (r^*, f^*) will be as follows:

$$r^* = \frac{b}{2}\left(\frac{1-c}{1+b}\right)$$
$$f^* = \frac{1}{4}\left(\frac{1-c}{1+b}\right)^2$$
$$0 \leq f^* \leq (q^*)^2 = \left[\frac{1-c}{2(1+b)}\right]^2 = \frac{1}{4}\left(\frac{1-c}{1+b}\right)^2$$
$$\Pi_j^* = 2r^*q^* + 2(q^*)^2 = 2q^*(r^* + q^*)$$

Then, replacing to r and q, the joint profit model in two-part tariff contract scheme will be:

$$\Pi_j^* = \frac{1}{2}\left(\frac{1-c}{1+b}\right)(1-c)$$

$$r^* = bq^*,\ f^* = (q^*)^2,$$

$$\Pi_j^* = (1-c)q^*$$

2-2-2. Under unit-fee scheme

Given $(q_1^u, q_2^u, \pi_1^u, \pi_2^u)$, the PA will choose r^u to solve the problem of

$$\max \Pi_j = \pi_p + \pi_1^u + \pi_2^u$$

$$\Pi_j = r(q_1^u + q_2^u) + (q_1^u)^2 + (q_2^u)^2$$

$$\Pi_j^u = 2rq^u + 2(q^u)^2 = 2q^*(r + q^*)$$

$$\frac{\partial \Pi_j^u}{\partial r} = b(1-c) - 2(1+b)r = 0$$

In this case, the equation for $(q_1^u, q_2^u, \pi_1^u, \pi_2^u)$ is the same as under two-part tariff scheme. $p_1^* = p_1^u$, $p_2^* = p_2^u$, $q_1^* = q_1^u$, $q_2^* = q_2^u$. Therefore, the maximization of PA's profit for r^u will be as follows:

$$r^u = \frac{b}{2}\left(\frac{1-c}{1+b}\right),\ f^u = 0$$

This case makes the joint profit maximization under the two-part tariff and under unit fee is equal:

$$\Pi_j^u = \Pi_j^*$$

$$\Pi_j^u = \frac{1}{2}\left(\frac{1-c}{1+b}\right)(1-c)$$

2-2-3. Under fixed-fee scheme

Given $(q_1^f, q_2^f, \pi_1^f, \pi_2^f)$, the PA will choose f^f to solve the problem of

$$\max \Pi_j = \pi_p + \pi_1^f + \pi_2^f$$
$$\Pi_j = 2f + (q_1^f)^2 - f + (q_2^f)^2 - f$$
$$\Pi_j^f = 2(q^f)^2$$
$$\frac{\partial \Pi_j}{\partial f} = 0$$

However, if the TOC's profit is less than zero, the negotiation itself cannot be signed. So, the following conditions should be maintained:

$$\pi_1^f = (q_1^f)^2 - f \geq 0$$
$$\pi_2^f = (q_2^f)^2 - f \geq 0$$

Because of $q_1^f = q_2^f = q^f$, and $f = q^f$; r always has to be a positive value due to the conditions of b and c. Therefore, the maximization of PA's profit for f^f will be as follows:

$$f^f = (q^f)^2$$
$$\Pi_j^f = 2(q^f)^2$$
$$r^f = 0, \quad 0 \leq f^f \leq \left(\frac{1-c}{2+b}\right)^2$$

Because of $0 \leq f^f \leq (q^f)^2 = \left(\frac{1-c}{2+b}\right)^2$, the joint profit under fixed fee contract scheme will be as follows:

$$\Pi_p^f = 2\left(\frac{1-c}{2+b}\right)^2$$

2-2-4. Under mixed-fee scheme

Given $(q_1^m, q_2^m, \pi_1^m, \pi_2^m)$, the PA will choose $(r^m, f^m)$to solve the problem of

$$\max \Pi_j = \pi_p + \pi_1^m + \pi_2^m$$

$$\Pi_j = f + rq_2^m + (q_1^m)^2 - f + (q_2^m)^2$$

$$\Pi_j^m = (q_1^m)^2 + q_2^m(r + q_2^m)$$

First order for (r^m, f^m) will be

$$\frac{\partial \Pi_j}{\partial r} = q_2^m + r\frac{b}{4-b^2} + \frac{-4}{4-b^2}q_1^m + \frac{2b}{4-b^2}q_2^m = 0$$

$$\frac{\partial \Pi_j}{\partial f} = 0$$

$$\frac{\partial \Pi_j}{\partial r} = (1-c)(2-b)^2 + \left[2b^2 + 2(4-b^2)b + 8\right]r = 0$$

However, if the TOC's profit is less than zero, the negotiation itself cannot be signed. So, the following conditions should be maintained:

$$\pi_1^m = (q_1^m)^2 - f \geq 0,$$

$$r^m \geq 0$$

Therefore, the maximization of PA's profit for (r^m, f^m) will be as follows:

$$f^m = (q_1^m)^2, \;\; r^m = 0$$

$$\Pi_j^m = r^m q_2^m + (q_1^m)^2 + (q_2^m)^2 = (q_1^m)^2 + (q_2^m)^2 = 2\left(\frac{1-c}{2+b}\right)^2$$

Thus, the joint profit under mixed fee contract scheme will be as follows:

$$\Pi_j^m = 2\left(\frac{1-c}{2+b}\right)^2.$$

3. Cournot coordination

3-1. Under two-part tariff scheme

Given (q_1^*, q_2^*), the PA will choose (r^*, f^*) to solve the problem of

$$\max \Pi_j = \pi_p + \pi_1^* + \pi_2^*$$

The decentralized profit equation will be:

$$\Pi_j = 2f + r(q_1 + q_2) + p_1 q_1 - (c+r)q_1 - f + p_2 q_2 - (c+r)q_2 - f$$
$$\Pi_j = (p_1 - c)q_1 + (p_2 - c)q_2$$

The Kuhn-Tuker conditions for r and f are

$$\frac{\partial \Pi_j}{\partial r} = 0, \quad \frac{\partial \Pi_j}{\partial f} = 0$$
$$r^* = 0, \ f^* = 0$$

Given (r^*, f^*), the PA will choose q_1^* to solve the problem of $\max \pi_1$

$$\frac{\partial \pi_1}{\partial q_1} = 1 - 2q_1 - bq_2 - (c+r) = 0$$
$$q_1 = \frac{1 - bq_2 - (c+r)}{2}$$

Given (r^*, f^*), the PA will choose q_2^* to solve the problem of $\max \pi_2$

$$\frac{\partial \pi_2}{\partial q_2} = 1 - 2q_2 - bq_1 - (c+r) = 0$$
$$q_2 = \frac{1 - bq_1 - (c+r)}{2}$$

By solving the simultaneous equation, the quantity and decentralized profit equation for TOCs can be obtained:

$$q_1^* = \frac{1-c}{2+b}, \quad q_2^* = \frac{1-c}{2+b}$$
$$\Pi_j^* = 0 \ \pi_1^* = 0 \ \pi_2^* = 0$$

3-2. Under unit-fee scheme

Given unit fee r, operators choose optimal quantities (q_1^u, q_2^u) to solve the following problems. By letting $f=0$ at (r, f), a given unit-fee scheme and operator i's profit function becomes π_i with $f=0$. Given $(q_1^u, q_2^u, \pi_1^u, \pi_2^u)$, the PA will choose (r^u, f^u) to solve the maximization of total profit:

$$\max \Pi_j = \pi_p + \pi_1^u + \pi_2^u$$
$$\Pi_j^u = r(q_1^u + q_2^u) + (q_1^u)^2 + (q_2^u)^2$$
$$\Pi_j^u = 2rq^u + 2(q^u)^2 = 2q^*(r + q^*)$$

The Kuhn-Tuker conditions for r and f are

$$\frac{\partial \Pi_j^u}{\partial r} = b(1-c) - 2(1+b)r = 0$$
$$r^u = \frac{b}{2}\left(\frac{1-c}{1+b}\right),\ f^u = 0$$

As the total profit in two-part tariff scheme are equal to one in unit fee scheme, the equation will be formulated as follows:

$$\Pi_j^u = \Pi_j^*$$
$$\Pi_j^u = \frac{1}{2}\left(\frac{1-c}{1+b}\right)(1-c)$$

3-3. Under fixed-fee scheme

By letting *r=0* at (*r, f*), a fixed-fee scheme and each TOC's profit function become π_i with *r=0*. Given $(q_1^f, q_2^f, \pi_1^f, \pi_2^f)$, the PA will choose f^f to solve the problem of

$$\max \Pi_j = \pi_p + \pi_1^f + \pi_2^f$$
$$\Pi_j^f = 2f + (q_1^f)^2 - f + (q_2^f)^2 - f$$
$$\Pi_j^f = 2(q^f)^2$$

The first order condition for *f* is

$$\frac{\partial \Pi_j}{\partial f} = 0 .$$

For maintaining the condition in positive, these conditions are assumed:

$$\pi_1^f = (q_1^f)^2 - f \geq 0 \text{ and } \pi_2^f = (q_2^f)^2 - f \geq 0$$

Then the fixed royalty (*f*) is assumed equal to *q* at least.

$$q_1^f = q_2^f = q^f, \; f = q^f$$
$$f^f = (q^f)^2$$

So, the joint profit will be equal to

$$\Pi_j^f = 2(q^f)^2$$

As the assumption of $r^f = 0$ and $0 \leq f^f \leq \left(\frac{1-c}{2+b}\right)^2$, then fixed royalty assumption will be:

$$0 \leq f^f \leq (q^f)^2 = \left(\frac{1-c}{2+b}\right)^2$$

And the expansion of joint profit will be:

$$\Pi_p^f = 2\left(\frac{1-c}{2+b}\right)^2$$

3-4. Mixed-fee scheme

Given fixed fee f and r, the operator 1 chooses optimal quantity q_1^m, and the operator 2 chooses optimal quantity q_2^m. Given $(q_1^m, q_2^m, \pi_1^m, \pi_2^m)$, the PA will choose (r^m, f^m) to solve the problem of decentralized profit:

$$\max \Pi_j = \pi_p + \pi_1^m + \pi_2^m$$

$$\Pi_j^m = f + r q_2^m + (q_1^m)^2 - f + (q_2^m)^2$$

$$\Pi_j^m = (q_1^m)^2 + q_2^m (r + q_2^m)$$

The first order conditions for r and f is

$$\frac{\partial \Pi_j}{\partial r} = q_2^m + r\frac{b}{4-b^2} + \frac{-4}{4-b^2} q_1^m + \frac{2b}{4-b^2} q_2^m = 0$$

$$\frac{\partial \Pi_j}{\partial f} = 0$$

$$\frac{\partial \Pi_j}{\partial r} = (1-c)(2-b)^2 + \left[2b^2 + 2(4-b^2)b + 8\right] r = 0$$

For maintaining the condition in positive, these conditions are assumed:

$$\pi_1^m = (q_1^m)^2 - f \geq 0,\ r^m \geq 0$$

$$f^m = (q_1^m)^2,\ r^m = 0$$

Placing these equations into main, the joint profit equation will be

$$\Pi_j^m = r^m q_2^m + (q_1^m)^2 + (q_2^m)^2 = (q_1^m)^2 + (q_2^m)^2 = 2\left(\frac{1-c}{2+b}\right)^2$$

$$\Pi_j^m = 2\left(\frac{1-c}{2+b}\right)^2$$

4. Collusion coordination

4-1. Under two-part tariff scheme

The PA and the TOCs will choose (r^*, f^*, q^*) to solve the problem of

$$\max \Pi_j = \pi_p + \pi_1 + \pi_2$$

$$s.t. q = q_1 + q_2,\ q_1^* = q_2^* \text{and } b = 1,\ p = 1 - q$$

$$\Pi_j = 2f + rq + pq - (c+r)q - 2f$$

$$\Pi_j = (p-c)q$$

By taking the derivative of above-mentioned formula and set it equal to zero, the first order conditions with respect to *r, f, q* can be:

$$\frac{\partial \Pi_j}{\partial r} = 0,\ \frac{\partial \Pi_j}{\partial f} = 0,\ \frac{\partial \Pi_j}{\partial q} = 1 - 2q - c = 0$$

Maintaining the r and f in positive, it is assumed as follows:

$$0 \le r \le 1 - q_1 - q_2 - c - \frac{f}{q_1},\ 0 \le f \le (1 - q_1 - q_2 - c)q_1$$

Minimizing the condition, the equation is obtained as

$$0 \le r^* \le \frac{1-c}{2},\ 0 \le f^* \le \frac{(1-c)^2}{8}$$

In this case, q and p equations can be easily found:

$$q^* = \frac{1-c}{2},\ q_1^* = q_2^* = \frac{1-c}{4},\ p_1^* = p_2^* = \frac{1+c}{2}$$

Replacing the equations, the profit of PA and TOCs as well as their joint profit will be as follows:

$$\pi_p^* = 2f^* + \frac{1-c}{2}r^*,\ \pi_1^* = \pi_2^* = \frac{1}{2}\left(\frac{1-c}{2}\right)^2 - \frac{1-c}{4}r^* - f^*$$

$$\Pi_j^* = \left(\frac{1-c}{2}\right)^2$$

4-2. Under unit fee scheme

The PA and the TOCs will choose (r^u, q^u) to solve the problem of

$$\max \Pi_j = \pi_p + \pi_1 + \pi_2$$

$$s.t. q = q_1 + q_2,\ q_1^u = q_2^u \text{ and } b = 1,\ p = 1 - q$$

$$\Pi_j = rq + pq - (c + r)q$$

$$\Pi_j = (p - c)q$$

By taking the derivative of above-mentioned formula and set it equal to zero, the first order conditions with respect to *r* can be:

$$\frac{\partial \Pi_j}{\partial r} = 0,\ \frac{\partial \Pi_j}{\partial q} = 1 - 2q - c = 0$$

Maintaining the r in positive value, it is assumed as follows:

$$0 \le r \le 1 - q_1 - q_2 - c,$$

$$0 \le r^u \le \frac{1-c}{2}$$

In this case, the equations for q and p are formulated as follows:

$$q^u = \frac{1-c}{2},$$

$$q_1^u = q_2^u = \frac{1-c}{4},$$

$$p_1^u = p_2^u = \frac{1+c}{2}$$

Replacing the equations, the profit of PA and TOCs as well as their joint profit will be as follows:

$$\pi_p^u = \frac{1-c}{2} r^u,$$

$$\pi_1^u = \pi_2^u = \frac{1}{2}\left(\frac{1-c}{2}\right)^2 - \frac{1-c}{4} r^u$$

$$\Pi_j^u = \left(\frac{1-c}{2}\right)^2$$

4-3. Under fixed fee scheme

The PA and the TOCs will choose (f^f, q^f) to solve the problem of

$$\max \Pi_j = \pi_p + \pi_1 + \pi_2$$

$$s.t. q = q_1 + q_2,\ q_1^f = q_2^f \text{ and } b = 1,\ p = 1 - q$$

$$\Pi_j = 2f + pq - cq - 2f$$

$$\Pi_j = (p - c)q$$

By taking the derivative of above-mentioned formula and set it equal to zero the first order conditions with respect to *r* and *q* can be:

$$\frac{\partial \Pi_j}{\partial r} = 0,\quad \frac{\partial \Pi_j}{\partial q} = 1 - 2q - c = 0$$

Maintaining the *f* in positive, it is assumed as follows:

$$0 \le f \le (1 - q_1 - q_2 - c)q_1$$

$$0 \le f^f \le \frac{(1-c)^2}{8}$$

Then, the equations for q and p can be formulated as follows:

$$q^f = \frac{1-c}{2},\quad q_1^f = q_2^f = \frac{1-c}{4},\quad p_1^f = p_2^f = \frac{1+c}{2}$$

Replacing the equations, the profit of PA and TOCs as well as their joint profit will be as follows:

$$\pi_p^f = 2f^f,$$

$$\pi_1^f = \pi_2^f = \frac{1}{2}\left(\frac{1-c}{2}\right)^2 - f^f$$

$$\Pi_j^f = \left(\frac{1-c}{2}\right)^2$$

4-4. Under mixed-fee scheme

The PA and the TOCs will choose (r^*, f^*, q^*) to solve the problem of

$$\max \Pi_j = \pi_p + \pi_1 + \pi_2$$

$$s.t. q = q_1 + q_2 \text{ and } b = 1,\ p = 1 - q$$

$$\Pi_j = f + rq_2 + pq - cq_1 - (c+r)q_2 - f$$

$$\Pi_j = (p-c)q$$

By taking the derivative of above-mentioned formula and set it equal to zero, the first order conditions with respect to r, f, q_1 and q_2 can be:

$$\frac{\partial \Pi_j}{\partial r} = 0,\ \frac{\partial \Pi_j}{\partial f} = 0,$$

$$\frac{\partial \Pi_j}{\partial q_1} = 1 - 2(q_1 + q_2) - c = 0,$$

$$\frac{\partial \Pi_j}{\partial q_2} = 1 - 2(q_2 + q_2) - c = 0$$

For maintaining the r and f in positive, it is assumed as follows:

$$0 \le r \le 1 - q_1 - q_2 - c - \frac{f}{q_2},$$

$$0 \le f \le (1 - q_1 - q_2 - c)q_1$$

By minimizing the equation, r and f are formulated as follows:

$$0 \le r^m \le \frac{1-c}{2},$$

$$0 \le f^m \le \frac{(1-c)^2}{8}$$

Then, the equations for q and p can be formulated as follows:

$$q^m = \frac{1-c}{2},\ q_1^m = q_2^m = \frac{1-c}{4},\ p_1^m = p_2^m = \frac{1+c}{2}$$

By formulating the equation, the profit of PA and TOCs as well as their joint profit will be as follows:

$$\pi_p^m = f^m + \frac{1-c}{4} r^m,$$

$$\pi_1^m = \frac{1}{2}\left(\frac{1-c}{2}\right)^2 - f^m,$$

$$\pi_2^m = \frac{1}{2}\left(\frac{1-c}{2}\right)^2 - \frac{1-c}{4} r^m$$

$$\Pi_j^m = \left(\frac{1-c}{2}\right)^2$$

5. Comparing the assumption models

5-1. Comparisons between schemes without coordination

The PA and the TOC profit maximization equations come through the non-coordination contract schemes (*See* Table 4). When the PA and TOCs attempt to maximize their profit separately, the non-coordinated profit maximization equations shows in each contract scheme the profit of PA is higher than the profit of TOC:

$$\pi_{TOC} < \pi_P$$

In case of b=c=0, PA can maximize profit in the highest point in each scheme, and the ranking is given as fixed fee is the highest, two-part tariff follows it, unit and mixed fee schemes comes in the end with equal condition. $b=0$, c = 0:

$$\pi_p^f > \pi_p^* > \pi_p^u = \pi_p^m$$

Table 4. PA and TOCs' profit maximization equation in non-coordination case

Schemes \ Profit	Terminal operators	Port Authority
Two-part tariff	$\pi_1^* = \pi_2^* = 0$	$\pi_p^* = \frac{3+b}{2}\left(\frac{1-c}{2+b}\right)^2$
Unit-fee	$\pi_1^* = \pi_2^* = \frac{1}{4}\left(\frac{1-c}{2+b}\right)^2$	$\pi_p^u = \frac{2+b}{2}\left(\frac{1-c}{2+b}\right)^2$
Fixed-fee	$\pi_1^f = \pi_2^f = 0$	$\pi_p^f = 2\left(\frac{1-c}{2+b}\right)^2$
Mixed-fee	$\pi_1^m = \pi_2^m = 0$	$\pi_p^m = \left(\frac{1-c}{2+b}\right)^2$

As b is increasing, when c is constant, the profit decreases in each scheme and the ranking positions maintains in same condition: $0 < b < 1$: $\pi_p^f > \pi_p^* > \pi_p^u > \pi_p^m$.

In case of $b=1$, fixed fee will be equal to two-part tariff scheme: $\pi_p^f = \pi_p^* > \pi_p^u > \pi_p^m$.

When c=1, then the profit converges on zero in every scheme.

Shortly, general comparison of this schemes will be $\pi_p^f \geq \pi_p^* > \pi_p^u \geq \pi_p^m$. In un-coordination cases, the fixed fee and the two-part tariff scheme are more favorable scheme on PA viewpoint, while unit fee and mixed fee schemes are less favorable.

5-2. Comparisons between schemes with coordination

The PA and TOC profit maximization equations come through the coordinated contract schemes (*See* Table 5). When the PA and TOCs want to maximize their profit, the coordinated profit maximization equations will be as follows.

According to the Figure 3, in case of b=c=0, PA can maximize profit in same degree in each scheme, b = c = 0: $\pi_p^* = \pi_p^u = \pi_p^f = \pi_p^m$.

As b is increasing, when c is constant, the profit decreases in each scheme and the two-part tariff and unit fee maintains a bit higher than fixed and mixed fees: $0 < b < 1$: $\pi_p^m = \pi_p^f < \pi_p^* = \pi_p^u$.

When c=1, then the profit converges on zero in every scheme: $\pi_p^* = \pi_p^u = \pi_p^f = \pi_p^m = 0$.

In incoordination case, unit fee and two-part tariff schemes is more favorable. The general comparison of these schemes will be

$$\pi_p^m = \pi_p^f \leq \pi_p^* = \pi_p^u.$$

Table 5. PA and TOCs' profit maximization equation in incoordination case

Schemes \ Profit	Terminal operators	Port Authority
Two part tariff	$\pi_1^* = (q_1^*)^2 - f$ $\pi_2^* = (q_2^*)^2 - f$	$\Pi_j^* = \frac{1-c}{2}\left(\frac{1-c}{1+b}\right)$
Unit fee	$\pi_1^u = \pi_2^u = \frac{1}{4}\left(\frac{1-c}{2+b}\right)^2$	$\Pi_j^u = \frac{1-c}{2}\left(\frac{1-c}{1+b}\right)$
Fixed fee	$\pi_1^f = (q_1^f)^2 - f$ $\pi_2^f = (q_2^f)^2 - f$	$\Pi_p^f = 2\left(\frac{1-c}{2+b}\right)^2$
Mixed fee	$\pi_1^m = 0$ $\pi_2^m = \left(\frac{1-c}{2+b}\right)^2$	$\Pi_j^m = 2\left(\frac{1-c}{2+b}\right)^2$

5-3. Comparisons between schemes with Cournot model

The PA and TOC contract schemes for profit maximization equations come through the Cournot model (*See* Table 6). When the PA and TOCs can maximize the profit together, the profit equations are still different to TOC and PA. Unit fee and mixed fee cases are favorable for TOCs, while the fixed and mixed contract schemes more favorable to PA.

Table 6. Contract scheme comparison through Cournot model

Schemes \ Profit	Terminal operators	Port Authority
Two-part tariff	$\pi_i^* = (q_i^*)^2 - f^*$	$\Pi_j^* = \frac{1-c}{2}\left(\frac{1-c}{1+b}\right)$
Unit fee	$\pi_i^u = \frac{1}{4}\left(\frac{1-c}{2+b}\right)^2$	$\Pi_j^u = \frac{1-c}{2}\left(\frac{1-c}{1+b}\right)$
Fixed fee	$\pi_i^f = (q_i^f)^2 - f^f$	$\Pi_p^f = 2\left(\frac{1-c}{2+b}\right)^2$
Mixed fee	$\pi_1^m = 0,\ \pi_2^m = \left(\frac{1-c}{2+b}\right)^2$	$\Pi_j^m = 2\left(\frac{1-c}{2+b}\right)^2$

In case of b=c=0, total profit can be in the same degree in each scheme:

$$\Pi_j^m = \Pi_j^f = \Pi_j^* = \Pi_j^u$$

As b is increasing, when c is constant, the profit decreases in each scheme and the two-part tariff and unit fee maintains a bit higher than fixed and mixed contract schemes, $0 < b < 1$:

$$\pi_p^m = \pi_p^f < \pi_p^* = \pi_p^u.$$

When c=1, then the profit converges on zero in every scheme: $\Pi_j^m = \Pi_j^f = \Pi_j^* = \Pi_j^u = 0$

Interestingly, when $0 < c < 1$, and b=0, Fixed and mixed contact schemes are slightly favorable than other two schemes: $\Pi_j^m = \Pi_j^f > \Pi_j^* = \Pi_j^u$.

So, the general comparison in total profit will be $\pi_p^m = \pi_p^f \leq \pi_p^* = \pi_p^u$, that is a unit contract scheme and two-part tariff schemes are the slightly more favorable case for PA. Of course, the PA ensures its profits are covered in the fixed-fee scheme, but also extra profits generates more profit for PA.

5-3. Comparisons between schemes with Collusion model

The profit maximization equations for TOC, PA and their integration in each contract scheme is collected (*See* Table 7 and 8).

In non-coordination and decentralized models, the profit of TOC in two-part tariff and unit fee is same and unit fee is considered more favorable choice for TOC. However, in the Collusion model, these schemes are different results from each other.

In same time, the similar results are generated for profit maximization for PA. the four contract scheme models are different from PA is generated. More interesting result is the model of integrated profit maximization model. The integration profit generated from both PA and TOCs are same in any contract scheme.

$$\Pi_j^m = \Pi_j^f = \Pi_j^* = \Pi_j^u.$$

Table 7. Contract scheme comparison through Collusion model - TOC

Schemes \ Profit	Terminal operators
Two-part tariff	$\pi_1^* = \pi_2^* = \frac{1}{2}\left(\frac{1-c}{2}\right)^2 - \frac{1-c}{4}r^* - f^*$
Unit fee	$\pi_1^u = \pi_2^u = \frac{1}{2}\left(\frac{1-c}{2}\right)^2 - \frac{1-c}{4}r^u$
Fixed fee	$\pi_1^* = \pi_2^* = \frac{1}{2}\left(\frac{1-c}{2}\right)^2 - f^f$
Mixed fee	$\pi_1^m = \frac{1}{2}\left(\frac{1-c}{2}\right)^2 - f^m$, $\pi_2^m = \frac{1}{2}\left(\frac{1-c}{2}\right)^2 - \frac{1-c}{4}r^m$

Table 8. Contract scheme comparison through Collusion model – PA profit and Joint profit

Schemes \ Profit	Port Authority	Joint Profit
Two part tariff	$\pi_p^* = 2f^* + \frac{1-c}{2}r^*$	$\Pi_j^* = \left(\frac{1-c}{2}\right)^2$
Unit fee	$\pi_p^u = \frac{1-c}{2}r^u$	$\Pi_j^u = \left(\frac{1-c}{2}\right)^2$
Fixed fee	$\pi_p^f = 2f^f$	$\Pi_j^f = \left(\frac{1-c}{2}\right)^2$
Mixed fee	$\pi_p^m = f^m + \frac{1-c}{4}r^m$	$\Pi_j^m = \left(\frac{1-c}{2}\right)^2$

5-4. Comparisons between coordination and non-coordination schemes

In this section, the profit maximization equations according to the sum of PA and TOCs are compared with non-coordination and incoordination cases. The total profit maximization is the summed equation of the PA and two TOCs' profit maximization:

$$\pi = \pi_{PA} + \pi_{TOC1} + \pi_{TOC2}$$

As given equations in Table 9, two-part tariff and unit fee contract schemes generates more profit than fixed and mixed contract schemes in same conditions. However, if PA and TOC integrated on profit maximization together, there are higher in each contract scheme (*See* Table 10.), only equal in fixed contract scheme.

Table 9. PA and TOCs' summed profit maximization equation within both coordination cases

	Non-coordination	Integration
Two part tariff	$\sum_{1,2,p} \pi_i^* = \frac{3+b}{2}\left(\frac{1-c}{2+b}\right)^2$	$\Pi_j^* = \frac{1-c}{2}\left(\frac{1-c}{1+b}\right)$
Unit-fee	$\sum_{1,2,p} \pi_i^u = \frac{3+b}{2}\left(\frac{1-c}{2+b}\right)^2$	$\Pi_j^u = \frac{1-c}{2}\left(\frac{1-c}{1+b}\right)$
Fixed-fee	$\sum_{1,2,p} \pi_i^f = 2\left(\frac{1-c}{2+b}\right)^2$	$\Pi_p^f = 2\left(\frac{1-c}{2+b}\right)^2$
Mixed-fee	$\sum_{1,2,p} \pi_i^m = \left(\frac{1-c}{2+b}\right)^2$	$\Pi_j^m = 2\left(\frac{1-c}{2+b}\right)^2$

The comparison results show the difference between non-coordination and coordination cases in graphically. The largest difference between schemes for two groups is in mixed fee contract scheme, where the joint profit in coordination case is double higher than the non-coordination one. There are slightly more differences in two-part tariff and unit fee contract cases. In other words, in the coordinated channel, the PA and TOC generates in more than twice the profit in decentralized channel. Thus, the coordinated channels result of more profitable in these contract schemes. Further, the ratio of coordinated profit effort in integrated channel to the effort in the non-coordinated channel increases steadily to increase. However, there is no difference between groups of fixed fee scheme, because in any case, only PA maintains some profit, while TOC takes risks.

Table 10. Comparison results of the sum profit maximization within both coordination cases

	Non-coordination vs. Coordination
Two-part tariff	$\sum_{1,2,p} \pi_i^* < \Pi_j^*$
Unit-fee	$\sum_{1,2,p} \pi_i^u < \Pi_j^*$
Fixed-fee	$\sum_{1,2,p} \pi_i^f = \Pi_j^f$
Mixed-fee	$\sum_{1,2,p} \pi_i^m < \Pi_j^m$

5-5. Contract scheme comparisons between Cournot and Collusion models

The equation comparison between decentralized and integrated models is summarized (*See* Table 11 and Table 12). The total channel profits in the integrated model will be greater than that in the decentralized model in fixed and mixed fee contract cases. This result is the same with the earlier results from the channel coordination literatures. This shows the incoordination results in the loss in profitability. The coordinated channel requests higher effort as well as more effective rent and tariff decisions resulting in significantly higher profits for integrating coordination.

The profit maximization equations in two-part tariff and unit fee schemes are equal in each group. The integrated profit maximization in fixed fee and mixed fee contract schemes is higher than the decentralized profit maximization. Another important result generated from equations, the integrated profit is the same in any contract scheme. This is main difference from other decentralized models.

Table 11. Contract scheme comparison equations between Cournot and Collusion models

	Cournot	Collusion
Two part tariff	$Cour\,\Pi_j^* = \left(\frac{1-c}{2}\right)^2$	$Coll\Pi_j^* = \left(\frac{1-c}{2}\right)^2$
Unit fee	$Cour\,\Pi_j^u = \left(\frac{1-c}{2}\right)^2$	$Coll\Pi_j^u = \left(\frac{1-c}{2}\right)^2$
Fixed fee	$Cour\Pi_p^f = 2\left(\frac{1-c}{3}\right)^2$	$Coll\Pi_j^f = \left(\frac{1-c}{2}\right)^2$
Mixed fee	$Cour\Pi_j^m = 2\left(\frac{1-c}{3}\right)^2$	$Coll\Pi_j^m = \left(\frac{1-c}{2}\right)^2$

Table 12. Contract scheme comparisons between Cournot and Collusion models

	Cournot vs. Collusion
Two-part tariff	$Cour\,\Pi_j^* = Coll\,\Pi_j^*$
Unit fee	$Cour\,\Pi_j^u = Coll\,\Pi_j^u$
Fixed fee	$Cour\,\Pi_j^f < Coll\,\Pi_j^f$
Mixed fee	$Cour\,\Pi_j^m < Coll\,\Pi_j^m$

3. Coordination through sharing the risk and revenue

1. Assumption

It has been assumed the condition for the coordination model through concession payment choices above, and now the initial part of the assumption will be used for our next coordination model. This is also created for the one PA and two TOCs condition. Here, the market demand functions faced by TOC_1 and TOC_2 are assumed to be respectively

$$p_1 = 1 - q_1 - bq_2$$
$$p_2 = 1 - q_2 - bq_1$$

where p_i is the price of unit cargo (TEU) charged by TOC_i, and q_i is the amount of cargo handled by TOC_i; $i = 1,2$. Parameter $b \in (0, 1)$ represents the service differentiation level. The larger is b, the lower is the differentiation degree of the services.

There will occur service costs of TOCs from wages of the labor and rents for gantries and other equipment and activities. Let

$$C_i(q_i) = c_i q_i, i = 1,2.$$

$c_i q_i$ is the cost function of the operator i to handle cargo amount q_i , where ci with $0 < c_i < 1$ is operator i's marginal service cost, i = 1,2.

The expansion of the cost function will be:

$$C_1(q_1) = c_1 q_{1,} \ 0 < c_1 < 1$$
$$C_2(q_2) = c_2 q_{2,} \ 0 < c_2 < 1$$
$$c_1 = c_2 = c$$

In this section, it is assumed how PA and TOCs can share the joint profit and risk which was formulated above section.

2. Sharing the joint profit

The first assumption of the formula is on how the PA and the TOC can share the joint profit. The total joint profit has covered the profit from fixed fee and unit fee between PA and TOC.

PA will take a fixed royalty from both TOCs (2*f*) and adjusted revenue comes from each unit fee from TOC_1 ($k_{11}(p_1\text{-}c)q_1$) and TOC_2 ($k_{12}(p_2\text{-}c)q_2$). At the same time, each TOC will get the other part of the adjusted revenue giving fixed royalty to the PA:

$$\pi_p = 2f + k_{11}(p_1 - c)q_1 + k_{12}(p_2 - c)q_2$$

$$\pi_1^o = (1 - k_{11})\pi_1 - f,$$

$$\pi_2^r = (1 - k_{12})\pi_2 - f$$

3. Sharing the market uncertainty

When the market demand comes differently than PA and TOC expected, then PA should guarantee the incentives for the gap loss from expected profit. The differentiation between real and expected profit, it is called as the absolute deviation ($e\pi_i - \pi_i$). As PA takes the fixed royalties from each TOC (2*f*), they should pay back the loss to TOCs by guaranteeing market demand risk. In other side, TOCs take guarantee incentives from PA and survive from the market risk:

$$\pi_p = 2f - k_{21}(e\pi_1 - \pi_1) - k_{22}(e\pi_2 - \pi_2)$$

$$\pi_1^o = \pi_1 + k_{21}(e\pi_1 - \pi_1) - f,$$

$$\pi_2^o = \pi_2 + k_{22}(e\pi_2 - \pi_2) - f$$

4. Sharing the market risk

The last model for sharing the joint profit is on how PA and TOC can share the risk. Here the risk covers both total profits and the absolute deviation.

PA takes fixed royalty fee (2*f*) and variable unit fee from each TOCs ($k_i\pi_i$) and gives back the unexpected loss in the market uncertainties ($k_i(e\pi_i - \pi_i)$).

$$\pi_p = 2f + k_{11}\pi_1 + k_{12}\pi_2 - k_{21}(e\pi_1 - \pi_1) - k_{22}(e\pi_2 - \pi_2)$$

At the same time, both TOCs take their part from unit fee ($(1 - k_i)\pi_i$) and guarantee covers for the loss ($k_i(e\pi_i - \pi_i)$), and pays the royalty fee (*f*) to PA. This mechanism makes both side more reliable and favorable partners during the long period.

$$\pi_1^s = (1 - k_{11})\pi_1 + k_{21}(e\pi_1 - \pi_1) - f,$$
$$\pi_2^s = (1 - k_{12})\pi_2 + k_{22}(e\pi_2 - \pi_2) - f$$
$$\Pi_j^s = \pi_1^s + \pi_2^s$$

Chapter 4. Numerical analysis and results

In the previous chapter, the multiple results of the integrated, decentralized and non-coordinated channels in the form of various propositions are compared with each other. The results of a representative numerical analysis are explained by some of the above results. Each contract scheme comparison is proved through numerical simulation. The simulation software used in the research is Excel and Graphing Calculator 3D programs. It is easy to draw mathematical equation graphics through this software.

The parameters used for the numerical simulation are:

$$\begin{cases} b = 0.\ c = 0. \\ b = 0.\ c = 1. \\ b = 1.\ c = 0. \\ b = 1.\ c = 1. \\ b\ is\ constant; 0 < c < 1. \\ c\ is\ constant,\ \ 0 < b < 1. \end{cases}$$

The impact of changes in cost on total channel profits is previewed. The results of the numerical analysis will be presented numerically and graphically in this section.

First, non-coordination channel case is compared (*See* Fig. 1 and Fig 2). It is attempting to check at cases involving similar and dissimilar values in profit coefficients through four contract schemes in non-coordination model. As shown in Figure 5 and 6, fixed fee contract scheme are higher for PA in non-coordination, because PA gets less risk than other cases. As the value of cost of PA decreases, the profit of PA increases till 50%. As the cost parameter c is fixed for 0.5, c=0.5; the profit in fixed fee contract increased over 10%, when the service increases up. When the parameter b is fixed to 0.5, b=0.5, the profit in the fixed contract increased over 25% as much as the cost decreases down. The PA can increase its profit to 9% in two-part tariff contracts, about 6%

in the unit and mixed contract cases as much service flexibility increases; 23% in two-part tariff contract, 16% in unit fee contract and 13% in mixed fee contract as much cost decreases. It is interesting to observe the profit coefficient is more elastic to the cost than service flexibility, that is, the profit increases rapidly as the cost changes than service flexibility changes in all contract schemes.

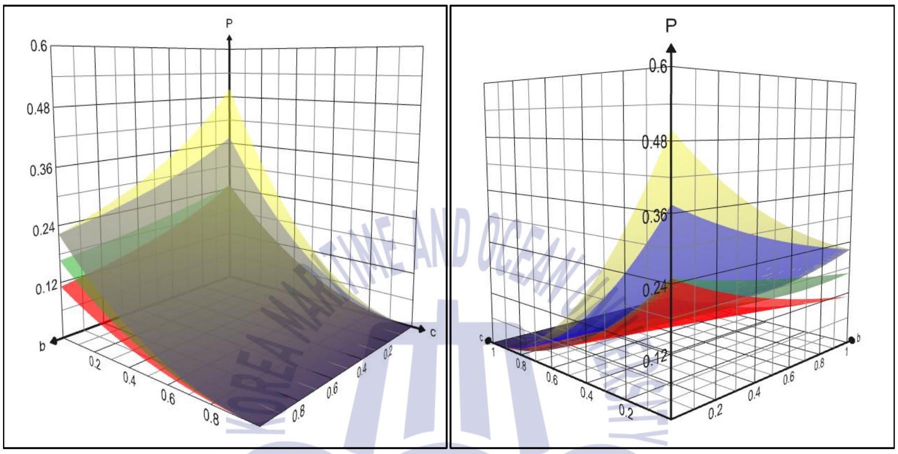

Figure 1. Comparison schemes in non-coordination channel in 3D

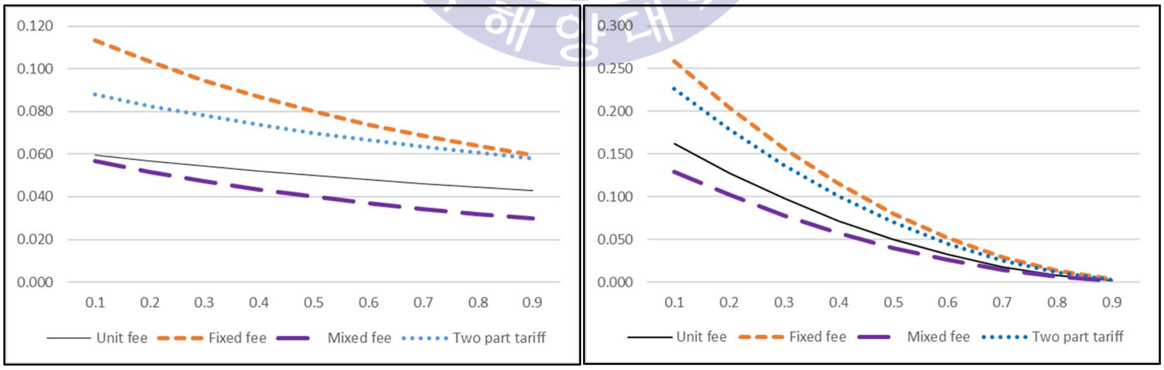

Figure 2. Comparison schemes in non-coordination channel

Second, the involving similar and dissimilar values in profit coefficients is compared through four contract schemes in coordination model. The two-part tariff and unit fee contract schemes are slightly higher in coordination, because PA and TOC make decisions depending other players' decisions (*See* Fig. 3 and Fig. 4). As the value of cost of PA decreases, the profit of PA increases till 50% in all contract schemes. As c=0.5, the profit in all contract schemes increased over 11%, when the service increases up due to the changes in service flexibility. When the parameter is b=0.5, the profit in unit fee and two-part tariff scheme increased over 27% and in fixed and mixed contracts to 26% as much as cost decreases (*See* Fig. 4). In this case, that the profit is more elastic to cost changes than service flexibility.

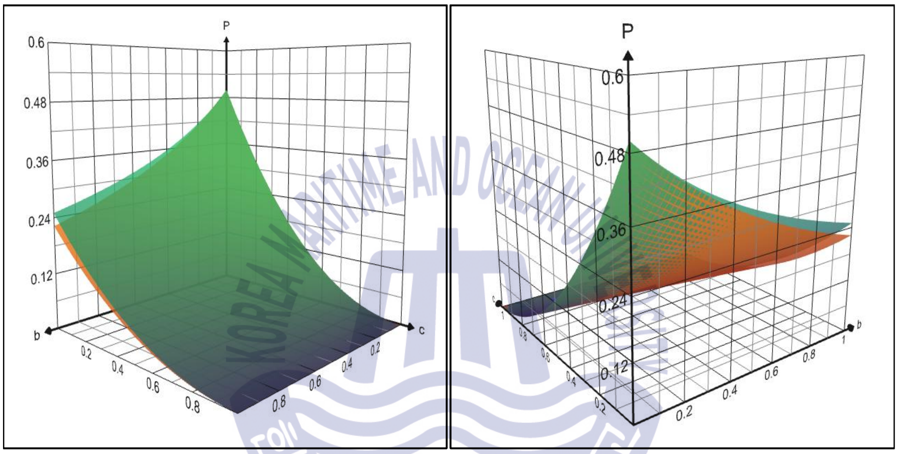

Figure 3. Comparison within coordination in 3D

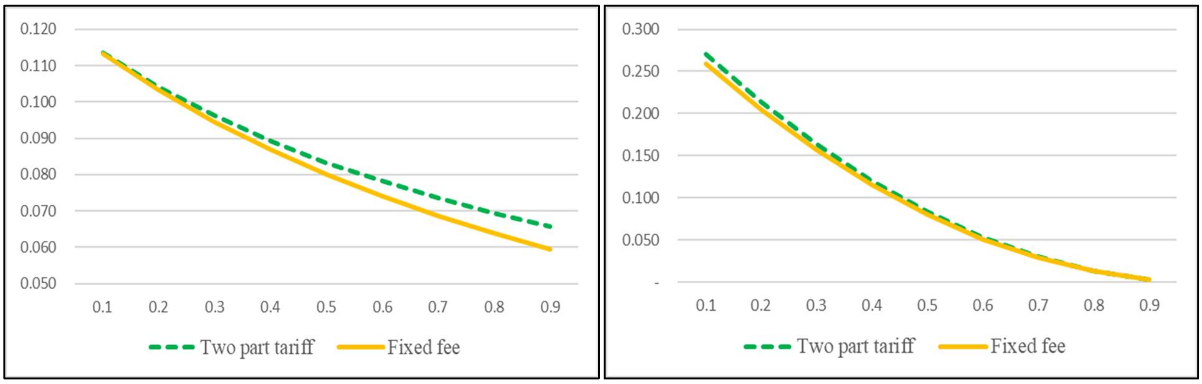

Figure 4. Comparison schemes within coordination

Continuously, the results of sum profit maximization are compared in each contract scheme.

As c=0.5, the profit in two-part tariff and unit fee contract schemes increased over 11% in coordination case and 9% in non-coordination case, due to the service flexibility increases up

(*See* Fig. 5). When the parameter is b=0.5, the profit in unit fee and two-part tariff scheme increased over 27% in coordination case than 24% in non-coordination, the difference between them decreases as much as cost increases. The profit in fixed fee contract scheme are same in both cases (*See* Fig. 6).

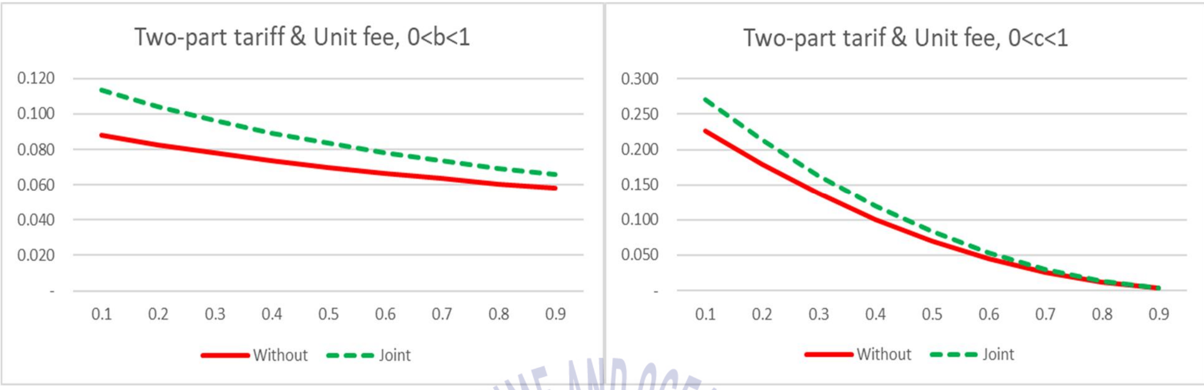

Figure 5. Comparison results of sum profit maximization in Two-part tariff and Unit fee schemes

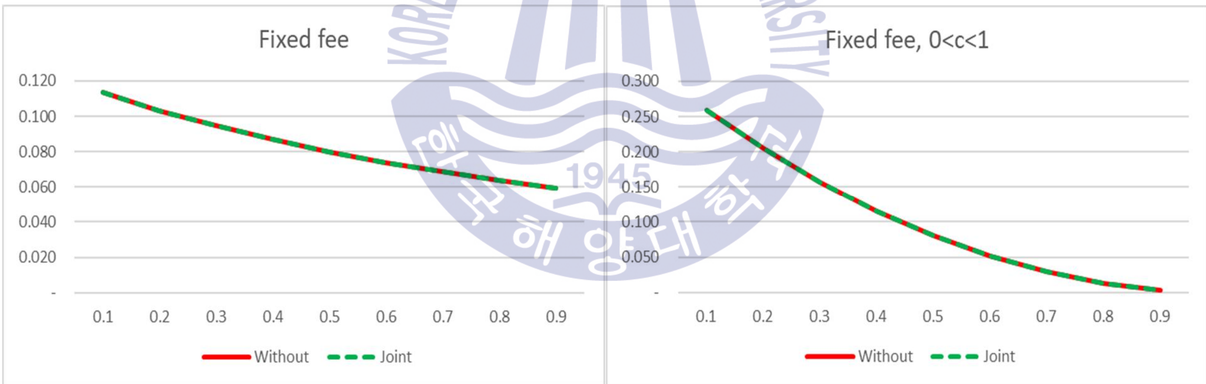

Figure 6. Comparison results of sum profit maximization in fixed fee scheme

The difference in total profit between non-coordination and coordination cases is given in mixed fee scheme. As c=0.5, the profit in mixed fee contract schemes increased over 11% in coordination case twice more than in non-coordination case (5.5%), as much as the service flexibility increases up (*See* Fig. 7). When the parameter is b=0.5, the profit in unit fee and two-part tariff scheme increased over 26% in coordination case twice more than in non-coordination

(13%); the difference between them decreases down as much as the cost increases.

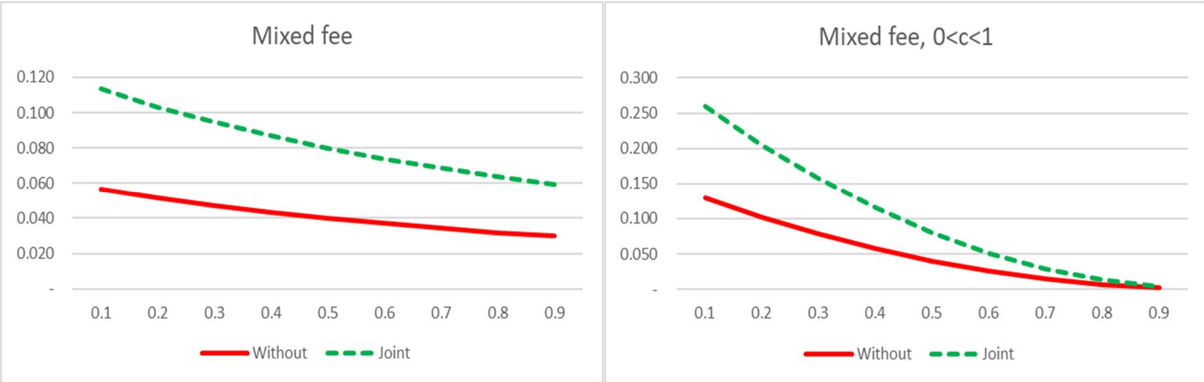

Figure 7. Comparison results of sum profit maximization in Mixed fee scheme

Next, the non-coordination channel case is compared thoroughly. It is found that the joint profits in all four contract schemes are equal. The joint profit increase depends on only how the PA and TOCs can decrease their cost as much as possible (*See* Fig.8). Despite of service flexibility changes, the joint profit will be positive in every contract scheme. This case decreases the worries of PA how to offer the contract to TOC. They should care only for the total cost generated.

Figure 8. Comparison results of sum profit maximization in non-coordination channel

Lastly, the contract schemes between Cournot and Collusion models are compared. As the cost coefficient is constant, the profit in two-part tariff and unit fee contract schemes becomes to constant 6% in both coordination models, despite of the service flexibility changes (See Fig. 9).

When the service parameter is constant, the profit in unit fee and two-part tariff scheme can reach over 20% in both coordination models, as much as cost increases. The profit in two-part tariff and unit fee contract scheme are same in both models.

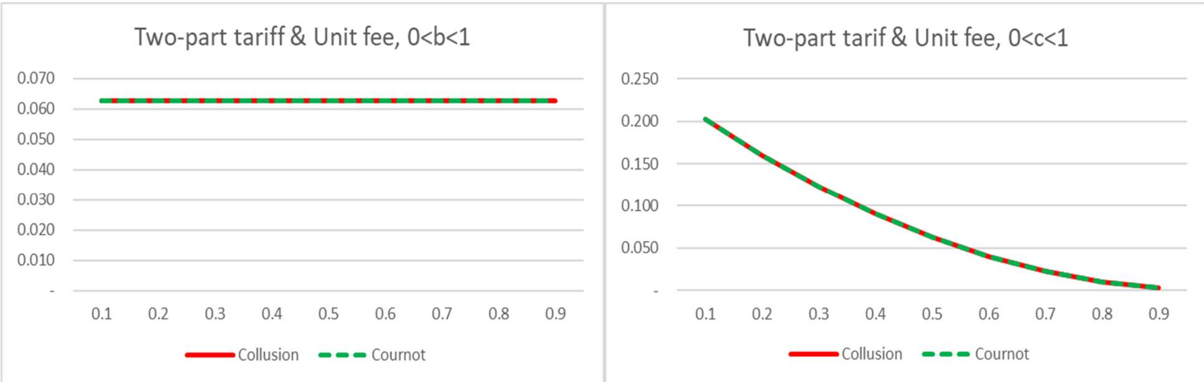

Figure 9. Comparison between Cournot and Collusion models – Two-part tariff and Unit fee schemes

But the profit in fixed and mixed fee contract schemes in Collusion model is higher than the one in Cournot model. As the cost coefficient is constant, the profit in fixed and mixed fee contract schemes becomes to constant 6% in Collusion model higher than Cournot (5.6%), despite of the service flexibility changes (*See* Fig. 10). When the service parameter is constant, the profit in fixed and mixed fee scheme can reach higher (over 20%) in the Collusion model than one (16%) in Cournot model, as much as cost increases.

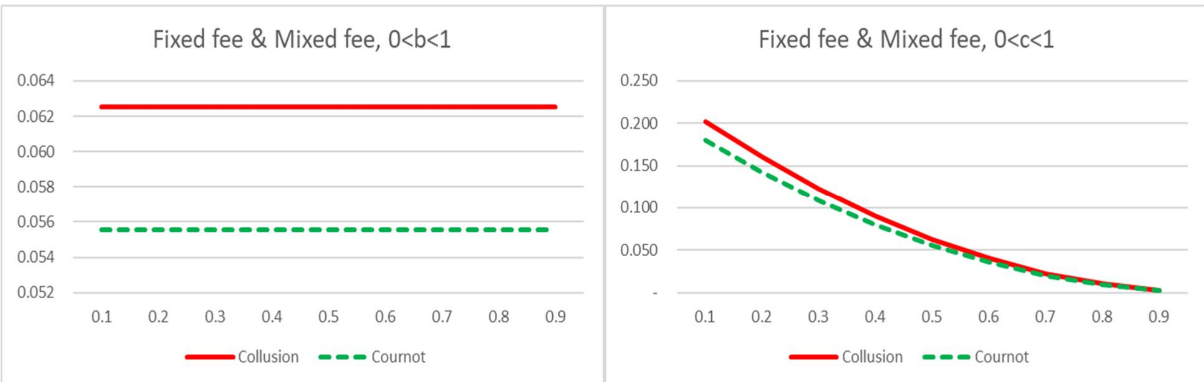

Figure 10. Comparison between Cournot and Collusion models – Fixed and Mixed fee schemes

Chapter 5. Conclusion

1. Summary

The rapid changes in global markets affect the port industry significantly. For achieving a competitive advantage PA and TOCs invested more in port facilities and equipment; but the competition with other TOCs and high requirements from shipping companies, TOCs have been stressing upon capturing demand to maintain its profitability. In the same condition, PA has been seeking a favorable position to maintain its competitiveness in the market region. Market uncertainty and technological changes bring PA and TOCs to work in collaboration to sustain better their operational and financial condition (UNCTAD, 2017).

There are very few studies were conducted. The qualitative and non-pragmatic studies cannot give a detailed solution to the issues with limitation and not proper with real time. Meanwhile, the previous studies focused on how PA can maximize their profit by only PA's perspective. This research has focused on how to connect two different perspective public and private entities into the way of a joint profit maximization. In order to achieve more profit in integration, the research aims to suggest the joint profit maximization model between them. The four types contract schemes offered by PA is compared in four model cases: without coordination, with coordination, Cournot and Collusion models.

In literature review part, it is reviewed on how PA and TOC operate differently through the agreement in the negotiated period. The landlord function model is more favorable and it operates in 60-70% in the world (Drewry Maritime Research, 2016). According to the model PA owns and manage port land infrastructures, while TOCs are responsible for terminal operations. In singing he leasehold contract PA and TOCs decide in which contract scheme they will negotiate whether fixed fee or unit fee. As comparing the port renting system in foreign countries, it is found that there are no absolute proper contract schemes. In Asia fixed and unit fee is offered separately, while in most of European PAs prefer to offer two-part tariff contracts.

As the port industry is accounted as oligopoly market, it is described generally on the channel coordination model with other oligopolistic game models, such as Bertrand, Cournot, and Stackelberg and Collusion models.

A module is conducted for each contract and then they are compared through numerical analysis. The research conclusions confirmed the previous studies. The fixed fee scheme is found favorable from PA perspective when they focus on maximizing their profit by increasing throughput, while two-part tariff and unit fee scheme is found favorable when PA maximize its profit by increasing port tariff with coordination with TOCs. Another result has been generated that PA can more profit when they offer a contract with coordination than they offer a contract without coordination. The results comparing the total profits generated by PA and TOCs is lower than the integrated profits of them. The comparison results show that joint coordination with collusion model is more positive than other models. By offering any contract schemes PA and TOC maintain the same the profit through Collusion model. Furthermore, it is modeled on how PA and TOCs can share the joint profit and risk.

In the next sections, some important implications will be suggested, the limitations of the study and further studies will be given.

2. Implications

The findings of the study provide meaningful implications to improve further plans. By observing the comparisons numerical analysis, the following major results can be:

When PA wishes to maximize its profit by increasing throughput, the fixed rental contract is more favorable choice. This result is consistent with Chen and Liu (2015). Typically, PA seeks to maximize fee revenues collected from TOCs through the rent contract, while the TOC seeks to maximize its fee revenues through a port tariff.

When PA wishes to maximize its profit by sharing market risk with TOCs, then two-part tariff and unit fee contracts are referred favorable choice. This result proves the study assumptions by Chen and Liu (2014) and Liu et al. (2018). As much PA tries to increase its profit, they should keep the connection with TOC by sharing profit and demand risk.

The results show that PA can more profit when they offer a contract with coordination than they offer only a contract without coordination. The coordination with TOC, the PA can increase revenue not only from the fixed rent but also sharing the profit generated from more throughput increase in the port.

The total sum of the profit of PA and two competitive TOCs is higher in two-part tariff and unit fee contract schemes. As much as PA covers the profit and risk of TOCs, so much TOC can increase the throughput. This gives more opportunity to maximize profit between PA and TOCs.

The difference from the total profit between parties, the integrated profit provides constant profits to the parties. When PA and two TOCs can focus on the integrated profit, then they can increase it more than in competitive condition. In this way, PA can give opportunity to TOCs to select proper contract scheme.

3. Limitation

The research study is modeled under channel coordination aiming to align the PA and TOCs by maximizing joint profit.

The main limitation of the study is data accessibility. Due to the private negotiation between PA and TOCs, the original data cannot be accessed. As the difficulty of the real data, the model is calculated through numerical analysis.

Second, the model is limited with only main parameters in assumption in order to find the optimal profit. As the range of the model parameters are selected between 0 to 1 to calculate through numerical analysis, the cost and service differentiation degree can be different in real life. Service differentiation and cost differentiation are not explained in detail. Moreover, the model doesn't cover full factors and conditions in practice.

Third, from previous studies, the equation that each TOC has same cost degree are formulated. When the model implies to the real conditions, it is suggested to care about the cost differentiation of the private companies.

4. Further studies

The research study is carried on as the first step of introduction of channel coordination on aligning the PA and TOCs on maximizing joint profit. The channel coordination is a more favorable model in the marketing of logistics, franchising, and other chain connected businesses. While it can adapt to small businesses easily, large corporations and public entities still find it difficult. Because most of the study related to this field has been continuously doing on theoretically and non-pragmatic ways.

For further studies, the model can be extended with more variables and parameters in detail. First, the research model assumes PA and TOCs can reach through full open information. For instance, PA cannot be informed on TOC full marginal services differentiation costs. In this case, it is necessary to resolve the model with real accessible data. This can be challenging effort to study. Moreover, characteristics of each draft are different due to condition and factors.

Second, our model consists of a limited number of players, the extension with multiple TOCs or with other PAs in the region can make a new challengeable study.

Last, it is assumed on profit and risk sharing between PA and TOCs, in real life can be occur misunderstanding on sharing. In this case, how PA can impose penalties which applied in real practice. Modeling this condition is also a worthy topic for the port industry.

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