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ABSTRACT

While the importance of inter-port competition and intra-port competition has been well recognized in the studies related to sea ports, few theoretical models have been developed with which the effects of competition on terminal concession awarding can be explicitly addressed. To fill this gap in research, this study proposes a non-cooperative game theory model, where two terminal operators apply for terminal concessions in two adjacent ports. The modelling results suggest that (a) a terminal operator's profit increases with its market power. As a result, it always prefers to control more terminals in the region; (b) However, when all terminal operators expanded their operations to every competing port in the region, they will be worse off due to an increase of inter and intra port competitions, a situation similar to the prisoners' dilemma; and (c) when a port authority has significant market power thus that it can charge a high price from, or share a large proportion of the terminal operators' revenue, the port authority would prefer to introduce inter and intra port competitions, rather than allowing one terminal operator to monopoly all terminals in the region. Empirical evidences consistent with these modelling results are discussed in the paper.

Keywords: Port Concession, Global Terminal Operators, Game Theory, Incentives

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1. INTRODUCTION

Most modern container terminals are run under a concession agreement model. A concession is an agreement between the port authority and the terminal operator in order to operate certain port facility over a period of time. Terminal concessions in seaports have recently attracted some academic attention. Studies such as Notteboom [1], Pallis, Notteboom and de Langen [2] and Theys et al. [3] have identified a detailed research agenda on issues such as concession allocation mechanisms, the determination of the concession term and concession fees, the inclusion of special clauses, concession site selection, division of risks and investment, performance target etc. Theys et al. [3] further pointed out that so far, insights from established economic theories have rarely been applied to terminal concessions in seaports. Therefore, there is a need to conduct detailed investigation and modelling analysis. This study aims to contributing to this burgeoning literature by proposing a game theoretical model with which the effects of competition on seaports terminal awarding can be analyzed.

Following the work by Goss [4], a substantial body of literature on port competition has been developed focusing mainly on economic efficiency, port choice and market share division. Murphy, Daley and Dalenberg [5] and Murphy and Daley [6] identified a list of important determining variables through a survey. According to Fleming and Hayuth [7], geographical location is vital to explaining a port's competitive success. Tongzon [8] examined the determining factors of overall port performance and productivity including location, frequency of ship calls, economic activity within the sector, labour and capital productivity and work practices within a port. Fung [9] tried to measure the competition between the Ports of Singapore and Hong Kong. Bichou and Gray [10] reviewed the terminologies, providing a descriptive starting point for model variables. Another group of quantitative studies have also been conducted to study port choice and port competition. Winston [11] used a multinomial probit analysis to predict the demand for domestic ocean container services, while Tsamboulas and Kapros [12] used a combination of statistical methods to correlate inter-modal transportation behaviour with the physical and economic criteria of the mode. Veldman and Buckmann [13] used a logit model to quantify factors affecting cargo routing decisions for major ports around Rotterdam. Brooks and Button [14] provided the determinants of shipping rates. Tiwari, Itoh and Doi [15] used a nested discrete choice method to analyze shippers' behaviour for containerized cargo in China. Nir, Lin and Liang [16] used a logit model to capture the distribution of export activity among Taiwan's three ports.

Several studies proposed that competition between terminal operators, or the so called "within port" or "intra port" competition, also has important effects on port performance and operations. According to the definition by World Bank [17], '*Intra-port competition refers to a situation where two or more different terminal operators within the same port are vying for the same market. In this case, the terminal operator has jurisdiction over an entirely terminal area, for berth to gate and competes with other terminal operators*'. Goss [4] pointed out intra-port competition is beneficial in that it prevents (monopolistic) rent seeking of port service providers. De Langen and Pallis [18] supported the introduction of intra – port competition, which leads to specialisation, flexible adaptation and innovation of terminal operators. Using an approach of cooperative game modelling, Saeed and Larsen [19] studied possible coalitions among the terminal operators in the Port of Karachi. They found a "grant coalition" among the three terminal operators leads to maximum total payoff. However, the real winner is the terminals in nearby ports who earn a higher profit without joining the coalition.

All these studies provided valuable insights on the competitive effects of port competition. However, few have analyzed the effects and roles of port competition on terminal concession awarding. In particular, while Theys et al. [3] pointed out that intra-port competition may be introduced if concessions are awarded to different operators, they did not discuss the conditions under which port and terminal operators would prefer such concession awarding.

Nor is clear how such practice would affect the payoffs of ports and terminal operators. There is an urgent need to fill this research gap: most ports around the world are facing competitive pressure from nearby ports, and many ports have introduced intra-port competition over the last two decades. This is particularly evident in China, where virtually all major ports have awarded concessions to multiple operators. The ownership structures of the major container ports in China are summarized as in Table 1.

Table 1. Ownership Structure of major Chinese container terminals

China	Port	Terminal	Operator
North China	Tianjin	Tianjin Five Continents International Container Terminal	COSCO (14%)
		Euroasia Terminal	APM (30%)
		Tianjin Phase 3	PSA (49%)
	Dalian	Dalian Container Terminal	APM (4.9%), PSA (34.6%),
		Dalian Dagang China Shipping Container Terminal	PSA (20.1%)
		Dalian Port Terminal	PSA (25%), COSCO (20%)
	Qingdao	Qingdao Qianwan Container Terminal	APM (20%), DPW (29%), COSCO (50%)
East China	Shanghai	Shanghai East Container Terminal (Waigaoqiao Phase 4)	APM (49%)
		Shanghai East Container Terminal (Waigaoqiao Phase 5)	HPH (50%)
		Shanghai Container Terminal	HPH (37%), COSCO (20%)
		Shanghai Pudong International Container Terminal	HPH (30%), COSCO (30%)
	Yangshan	Yangshan Port Phase 1	CMHI (15.3%)
		Yangshan Port Phase 2	APM (32%), HPH (32%), CMHI (4.8%)
	Ningbo	Ningbo Beilun International Terminal (Phase II)	HPH (49%)
	Xiamen	Xiamen International Container Terminal, berth 2 to 4	HPH (49%)
		Xiamen Songyu Container Terminal	APM (50%)
South China	Hong Kong	Modern Terminals	CMHI (27%)
		Hongkong International Terminal	HPH (65%), PSA (20%)
		COSCO-HIT Terminal	HPH (33.25%), COSCO (50%), PSA (10%)
		Terminal 3	PSA (33.3%), DPW (67%)
		Terminal 8 West	PSA (41%), DPW (50%)
	Shenzhen	Da Chan Bay Phase 1	MTL (65%), CMHI (17.6%)
		Shekou Container Terminal	DPW (22%), CMHI (53%)
		Chiwan Container Terminal	CMHI (26%)
		Yantian International Container Terminal	HPH (~40%), APM (~10%), COSCO (~50%)
		Shenzhen Mawan Terminals	CMHI (30%)

Sources: Terminal websites

Operators: COSCO = China Ocean Shipping Company, CMHI = China Merchants Holdings International, HPH = Hutchison Port Holdings, PSA = Port of Singapore Authority, DPW = Dubai Ports World, APM = A. P. Moller-Maersk, MTL = Modern Terminals

The introduction of intra-port competition appeared to have encountered more challenges in Europe, particularly from the marine industry (van Reeven [20]). On 13 February 2001, the European Commission adopted the Communication '*Reinforcing quality service in sea ports: A key for European transport*'. In this communication, the port services directive identified the introduction of intra-port competition as one of the main objectives. Nevertheless, this directive has been rejected twice by the European Parliament. This is remarkable since between 1999 and 2004, only three legislative proposals had been rejected. The representative of port authorities (ESPO and FEPORT), dockworkers (ITF, ETF, and IDC), tug owners (ETA), maritime pilots (EMPA), and boatmen (EBA) campaigned against the directive, and argued that competition between ports, so-called inter-port competition, would keep sufficient pressure on efficiency. Van Reeven [20] studied the effects of vertical separation between port authority and terminal operators where intra port competition is present. Using a horizontal product differentiation model in which two ports compete for cargo trans-shipments, he showed that the separation of port authority and terminal operators (the Landlord Port model) is Nash equilibrium, which yields the highest profits for the port industry and the highest prices for its customers. The introduction of intra-port competition into the Landlord Port model reduces industry profits and prices, which makes the port industry reluctant to open itself to such competition. The modelling results of van Reeven [20] are consistent with the actions taken by the European marine industry. Nevertheless, it does not fully explain why intra-port competition have been well accepted in some of the major ports, including those newly developed ports / terminals in China. Especially in China, many ports / terminals are run by multiple terminal operators, same operators are allowed to expand through winning concessions in competing ports.

This study proposes an analytical non-cooperative game theory model thus that the effects of competition on seaports terminal awarding can be investigated. Unlike most previous port concession studies which mainly focus on concession procedures and processes (Defilippi [21]; van Niekerk [22]; Notteboom [23]; Pallis, Notteboom and de Langen [2]), we aim to study the dynamic competition effects for port authorities and terminal operators. By modelling firm profits for two terminal operators serving two adjacent ports, we show that (a) a terminal operator's profits increase with its market power in the region. As a result, an operator always prefers to control more terminals. *Ceteris Paribus*, a terminal operator can increase its profit by expanding its operation into nearby ports. However, it is also found that (b) when all terminal operators expand to other ports, they will be worse off due to an increase of inter and intra port competitions. This is similar to the classic prisoners' dilemma. Terminal operators would be better off if they could simultaneously stay off their competitors' territory, although expansion in the region is the dominant strategy. Finally, it is found that (c) when a port authority has significant market power thus that it can charge a high price or share a large proportion of the terminal operators' revenue, the port authority would prefer to introduce inter and intra port competitions to the case of allowing one terminal operator to monopoly all terminals in the region.

This paper is organized as follows: Section 2 sets up the basic economic model, Section 3 represents and interprets the modelling results, Section 4 summarizes and concludes the paper.

2. THE BASIC MODEL

We model a case where two terminal operators, operator x and y, are applying for the concession rights in two adjacent seaports, port 1 and 2. Services in the two ports are substitutable but differentiated. In the simplest case, this represents a common scenario where two adjacent seaports serve overlapping but not completely identical catchments areas. In each port there are two terminals of which concession rights are to be awarded, either to one or two of the candidate terminal operators, namely firm *x* and *y*. Therefore, intra-port competition will be present if the two terminals within the same ports are awarded to two different operators. The two terminal operators are symmetric in the sense that within the same port, they provide homogenous services with identical constant marginal cost c. An accompanying assumption, as suggested by de Langen and Pallis [18], is that demand for each port is at least twice as large as the Minimum Efficient Scale (MES) for providing a port service. Denote the terminal operators with superscripts while ports with subscripts, thus that q_1^x and p_1^x denote the output and price for service provided by terminal operator *x* at port 1 respectively. Without loss of generality, output is measured by the number of containers handled, while price is the average fee paid by shipping lines. Following the modelling approach of Fu et al. [24] and Oum and Fu [25], the inverse demand function for the two ports is specified as follows:

$$\begin{cases} P_1 = a_1 - b_1 Q_1 - kQ_2 \\ P_2 = a_2 - kQ_1 - b_2 Q_2 \end{cases} \tag{1}$$

where P_i denotes the market price of terminal services while $Q_i = q_i^x + q_i^y$ denotes the total output at port *i* respectively. With this specification, k measures the degrees of substitutability between the two ports' terminal services. Since a port's demand is more sensitive to its own price than the competing port's price, $b_i \geq k$ should always hold, with the equality holds and only holds when services at the two ports are perfectly substitutable / homogenous. The demand functions in (1) correspond to a representative consumer maximizing a quadratic and strictly concave utility function as in (2), where q_0 represents the numeraire good (money).

$$U(Q_1, Q_2) = a_1 Q_1 + a_2 Q_2 - \frac{1}{2}(b_1 Q_1^2 + 2kQ_1 Q_2 + b_2 Q_2^2) + q_0 \tag{2}$$

The concavity condition implies $b_1 b_2 - k^2 > 0$. The condition of positive output quantities for both firms implies:

$$(a_1 b_2 - a_2 k) > 0 \text{ and } (a_2 b_1 - a_1 k) > 0 \tag{3}$$

In practice, port authorities charge a fixed payment on the terminal operators for the concession right, and share a proportion of the terminal operator's revenue (Drewry [26]). However, such fixed payments vary in amounts, and are often accompanied with additional clauses on port infrastructure investments, rebate for facility construction etc. Therefore, it is assumed here that in the long run, the profit of port *i*, $\prod_i$, only depends on port revenue, which is a proportion of the terminal price [27]. That is, port revenue per container received by port *i* is specified as $r \cdot P_i$. The sharing proportion *r* is assumed to be exogenously determined by either government regulation or industry practice. Therefore, the profit of port *i* is

$$\prod_i = r \cdot P_i \cdot (q_i^x + q_i^y) \tag{4}$$

For a terminal operator, say *x*, its profit at port *i* is

$$\pi_i^x = (1-r)\cdot P_i \cdot q_i^x - c\cdot q_i^x \tag{5}$$

and its total profit $\pi^x = \sum_{i=1}^{2} \pi_i^x$ is simply the sum of profits in the two ports.

The terminal awarding process is modelled as a two stage game. In Stage One, each port awards the two terminals to either one or two terminal operators. In Stage Two, terminal operators engage in Cournot competition. Both the ports and terminal operators are assumed to maximize their respective profits. Van Reeven [20] pointed out that in the case of port authorities, such profits may be a measure of the level of economic rents within the port industry. Hence, the port industry does not necessarily realise these profits, but may dissipate potential profits on inefficiencies, higher wages, larger number of staff employed, and so on.

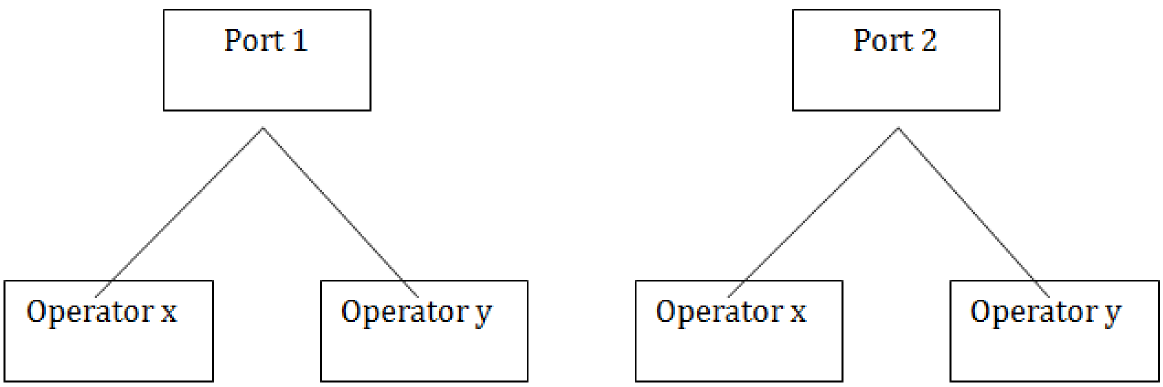
Since the two terminals operators are symmetric, it does not matter which terminal is awarded to a terminal operator. Thus the strategy / option for Port 1 can be summarized as three generic strategies: (1) to award the two terminals to operator *x*, denoted as (*xx*), or (2) to award the two terminals to operator *y*, denoted as (*yy*), or (3) to award the two terminals to two operators, denoted as (*xy*). Similarly, Port 2 has the same three generic strategies. This leads to nine possible concession awarding outcomes as summarized in Table 2:

Table 2. Pay Off Matrix of Terminal Awarding

Ports	Port 2			
	Strategy Space	Strategy 1	Strategy 2	Strategy 3
Port 1	Strategy 1	*(xx,xx)*	*(xx,yy)*	*(xx,xy)*
	Strategy 2	*(yy,xx)*	*(yy,yy)*	*(yy,xy)*
	Strategy 3	*(xy,xx)*	*(xy,yy)*	*(xy,xy)*

For example, market outcome of (*xy, xy*) refers to the case where both ports award their terminals to operator *x* and operator *y* respectively. Such a case is depicted as in figure 1.

Figure 1. Two level duopoly game of port competition



Since operators are symmetric, these 9 possible outcomes can be further classified into the following four scenarios:

1. Scenario 1. Each port is served by two terminal operators: this scenario includes outcome *(xy,xy).* In this case, there are both intra-port competition and inter-port competitions.

2. Scenario 2. Each port is served by one terminal operator only, but the terminal operators are different across ports: this scenario includes outcomes *(xx,yy), (yy,xx).* In this scenario, there is only inter-port competition present.
3. Scenario 3. Both ports (all four terminals) are awarded to the same terminal operator: this scenario includes *(xx,xx), (yy,yy)*. In such a case, one single terminal operator monopolies the regional market for terminal services.
4. Scenario 4. One port is awarded to one terminal operator only, but the other port is awarded to two different terminal operators: this scenario includes *(xx,xy), (yy,xy), (xy,xx), (xy,yy)*. In this scenario, there is inter-port competition and partial intra-port competition limited to one port.

While we have classified the 9 terminal awarding outcomes based on the strategy space of ports, which outcome will be chosen also depends on the relative market power between the ports (i.e., whether one port has competitive advantage with respect to the other one) as well as the relative market power between port authority and terminal operators (i.e., whether port authorities have greater bargain power, or terminal operators have greater bargain power). For example, if only port authorities have market power, then the standard approach to solve such a two-stage game is backward induction, which allows one to identify the Sub-game Perfect Nash Equilibrium. If only terminal operators have market power, then market outcome must be the result when terminal operators' dominant strategies are chosen. If neither the ports nor terminal operators have dominant market power over the other side, additional assumptions may be needed in order to obtain unique Nash Equilibrium. In any case, one needs to first solve ports and terminal operators' profits in the 4 scenarios in order to find out game players' preferences over different market outcomes.

3. MODELLING RESULTS

With this approach one first needs to solve firms' profits thus that to identify the preferences of port authorities and terminal operators. In this session we will solve the profits of ports and terminal operators for all the four Scenarios as identified in Section 2.

3.1 Stage II Cournot competition outcomes

We first solve for market outcome of Scenario 1. This scenario includes the case of *(xy,xy).* Operator *x* is awarded one terminal at each port thus that it chooses output q_1^x and q_2^x jointly to maximize its total profit:

$$\pi^x = \pi_1^x + \pi_2^x = [(1-r)P_1 - c]\cdot q_1^x + [(1-r)P_2 - c]\cdot q_2^x \tag{6}$$

This leads to the following First Order Conditions (FOCs):

$$\frac{\partial \pi^x}{\partial q_1^x} = (1-r)\left[a_1 - b_1(2q_1^x + q_1^y) - k(2q_2^x + q_2^y)\right] - c = 0 \tag{7.1}$$

$$\frac{\partial \pi^x}{\partial q_2^x} = (1-r)\left[a_2 - k(2q_1^x + q_1^y) - b_2(2q_2^x + q_2^y)\right] - c = 0 \tag{7.2}$$

Note since terminal operator 1 and 2 are symmetric, and they provide homogenous terminal services at a port, at equilibrium $q_i^x = q_i^y$ (*i*=1,2). Together with this condition it can be solved that at market equilibrium of stage 2 Cournot competition, we have

$$q_1^x = q_1^y = \frac{(a_1 b_2 - a_2 k) - \dfrac{c(b_2 - k)}{(1-r)}}{3(b_1 b_2 - k^2)} \quad (8.1)$$

$$q_2^x = q_2^y = \frac{(a_2 b_1 - a_1 k) - \dfrac{c(b_1 - k)}{(1-r)}}{3(b_1 b_2 - k^2)} \quad (8.2)$$

$$P_1 = \frac{a_1(1-r) + 2c}{3(1-r)}, \; P_2 = \frac{a_2(1-r) + 2c}{3(1-r)} \quad (8.3)$$

$$\pi^x = \pi^y = \frac{a_1(1-r) - c}{9(b_1 b_2 - k^2)}\left[(a_1 b_2 - a_2 k) - \frac{c(b_2 - k)}{(1-r)}\right] + \frac{a_2(1-r) - c}{9(b_1 b_2 - k^2)}\left[(a_2 b_1 - a_1 k) - \frac{c(b_1 - k)}{(1-r)}\right] \; (8.4)$$

$$\Pi_1 = r \cdot P_1 \cdot Q_1 = \frac{2r[a_1(1-r) + 2c][(1-r)(a_1 b_2 - a_2 k) - (b_2 - k)c]}{9(1-r)^2 (b_1 b_2 - k^2)} \quad (8.5)$$

$$\Pi_2 = r \cdot P_2 \cdot Q_2 = \frac{2r[a_2(1-r) + 2c][(1-r)(a_2 b_1 - a_1 k) - (b_1 - k)c]}{9(1-r)^2 (b_1 b_2 - k^2)} \quad (8.6)$$

Using a similar approach, and imposing symmetry for the terminal operators *x* and *y* where appropriate, it can be solved that the outcomes of the Cournot competition in Stage 2 are as follows:

In Scenario 2, which includes the outcomes of *(xx,yy), (yy,xx),* operator *x* and *y* each monopolies the terminal operations in one port. Since the two terminal operators are symmetric, without loss of generality, let *x* serves port 1 while *y* operates port 2. The Cournot competition outcomes are as follows, where q_1^x and q_2^y are each terminal operator's outputs, which are also the ports' outputs:

$$q_1^x = \frac{2b_2\left(a_1 - \dfrac{c}{1-r}\right) - k\left(a_2 - \dfrac{c}{1-r}\right)}{4b_1 b_2 - k^2}, \; q_2^y = \frac{2b_1\left(a_2 - \dfrac{c}{1-r}\right) - k\left(a_1 - \dfrac{c}{1-r}\right)}{4b_1 b_2 - k^2} \quad (9.1)$$

$$\pi^x = \frac{b_1[(2b_2 a_1 - a_2 k)(1-r) - (2b_2 - k)c]^2}{(1-r)(4b_1 b_2 - k^2)^2}, \; \pi^y = \frac{b_2[(2b_1 a_2 - a_1 k)(1-r) - (2b_1 - k)c]^2}{(1-r)(4b_1 b_2 - k^2)^2} \quad (9.2)$$

$$\Pi_1 == \frac{r[b_1(1-r)(2b_2 a_1 - a_2 k) + c(2b_1 b_2 + b_1 k - k^2)][(1-r)(2b_2 a_1 - a_2 k) - (2b_2 - k)c]}{(1-r)^2 (4b_1 b_2 - k^2)^2} \quad (9.3)$$

$$\Pi_2 == \frac{r[b_2(1-r)(2b_1 a_2 - a_1 k) + c(2b_1 b_2 + b_2 k - k^2)][(1-r)(2b_1 a_2 - a_1 k) - (2b_1 - k)c]}{(1-r)^2 (4b_1 b_2 - k^2)^2} \quad (9.4)$$

Scenario 3 includes the outcomes of *(xx,xx)* and *(yy,yy)*. One operator, say *x*, monopolies the operations of both ports. The other operator, *y* in this case, is blocked from the services in this region and earns zero profit. In this case, operator *x* coordinates the operations in both ports to maximize its profit and thus the outputs and firms' profits are as follows:

$$q_1^x = \frac{a_1 b_2 - a_2 k - \frac{c(b_2 - k)}{1-r}}{2(b_1 b_2 - k^2)}, \; q_2^x = \frac{a_2 b_1 - a_1 k - \frac{c(b_1 - k)}{1-r}}{2(b_1 b_2 - k^2)} \tag{10.1}$$

$$P_1 = \frac{1}{2}(a_1 + \frac{c}{1-r}), \; P_2 = \frac{1}{2}(a_2 + \frac{c}{1-r}) \tag{10.2}$$

$$\pi^x = \frac{[(1-r)a_1 - c]\left[a_1 b_2 - a_2 k - \frac{c(b_2 - k)}{1-r}\right]}{4(b_1 b_2 - k^2)} + \frac{[(1-r)a_2 - c]\left[a_2 b_1 - a_1 k - \frac{c(b_1 - k)}{1-r}\right]}{4(b_1 b_2 - k^2)} \tag{10.3}$$

$$\Pi_1 = \frac{r(a_1 + \frac{c}{1-r})\left[a_1 b_2 - a_2 k - \frac{c(b_2 - k)}{1-r}\right]}{4(b_1 b_2 - k^2)}, \; \Pi_2 = \frac{r(a_2 + \frac{c}{1-r})\left[a_2 b_1 - a_1 k - \frac{c(b_1 - k)}{1-r}\right]}{4(b_1 b_2 - k^2)} \tag{10.4}$$

Scenario 4 includes the outcomes of *(xx,xy), (yy,xy), (xy,xx), (xy,yy)*, such that one port concession is awarded to one single operator only, while the other port is served by two terminal operators. Without loss of generality, we consider the case of *(xy,yy)* where terminal operator *x* maximizes its profit by setting its output in port 1, q_1^x, so that $\pi^x = [(1-r)P_1 - c]q_1^x$, while terminal operator *y* maximizes its profits by jointly setting its outputs so that $\pi^y = [(1-r)P_1 - c]q_1^y + [(1-r)P_2 - c]q_2^y$. It can be solved that the Cournot competition yields:

$$q_1^x = \frac{1}{3}\left[\frac{a_1}{b_1} - \frac{c}{b_1(1-r)}\right], \; q_1^y = \frac{1}{3b_1}\left(a_1 - \frac{c}{1-r}\right) - \frac{1}{b_1} \frac{\left(a_2 - \frac{c}{1-r}\right) - \frac{k}{b_1}\left(a_1 - \frac{c}{1-r}\right)}{\frac{2b_2}{k} - \frac{2k}{b_1}} \tag{11.1}$$

$$q_2^y = \frac{\frac{1}{k}\left(a_2 - \frac{c}{1-r}\right) - \frac{1}{b_1}\left(a_1 - \frac{c}{1-r}\right)}{\frac{2b_2}{k} - \frac{2k}{b_1}} \tag{11.2}$$

$$\pi^x = \frac{[a_1(1-r) - c]^2}{9b_1(1-r)} \tag{11.3}$$

$$\pi^y = (1-r)\frac{1}{3}\left(a_1 - \frac{c}{1-r}\right) \times \left[\frac{1}{3b_1}\left(a_1 - \frac{c}{1-r}\right) - \frac{1}{b_1} \frac{\left(a_2 - \frac{c}{1-r}\right) - \frac{k}{b_1}\left(a_1 - \frac{c}{1-r}\right)}{\frac{2b_2}{k} - \frac{2k}{b_1}}\right]$$

$$
+\left\{\begin{array}{l} k\left[\dfrac{1}{3b_1}\left(a_1-\dfrac{c}{1-r}\right)-\dfrac{1}{b_1}\dfrac{\left(a_2-\dfrac{c}{1-r}\right)-\dfrac{k}{b_1}\left(a_1-\dfrac{c}{1-r}\right)}{\dfrac{2b_2}{k}-\dfrac{2k}{b_1}}\right]+ \\ b_2\dfrac{\dfrac{1}{k}\left(a_2-\dfrac{c}{1-r}\right)-\dfrac{1}{b_1}\left(a_1-\dfrac{c}{1-r}\right)}{\dfrac{2b_2}{k}-\dfrac{2k}{b_1}} \end{array}\right\} \quad (11.4)
$$

$$
\times(1-r)\frac{\dfrac{1}{k}\left(a_2-\dfrac{c}{1-r}\right)-\dfrac{1}{b_1}\left(a_1-\dfrac{c}{1-r}\right)}{\dfrac{2b_2}{k}-\dfrac{2k}{b_1}}
$$

$$
\Pi_1=\frac{-r[a_1(1-r)+2c]}{18b_1(1-r)^2(b_1b_2-k^2)}\left((a_1k^2+3ka_2b-4a_1b_1b_2)(1-r)+4cb_1b_2-ck^2-3kcb_1\right) \quad (11.5)
$$

$$
\Pi_2=r\left\{\begin{array}{l} a_2-\dfrac{k}{b_1}\left[\dfrac{2}{3}\left(a_1-\dfrac{c}{1-r}\right)-\dfrac{b_1k\left(a_2-\dfrac{c}{1-r}\right)-k^2\left(a_1-\dfrac{c}{1-r}\right)}{2b_1b_2-2k^2}\right] \\ -b_2\dfrac{b_1\left(a_2-\dfrac{c}{1-r}\right)-k\left(a_1-\dfrac{c}{1-r}\right)}{2b_1b_2-2k^2} \end{array}\right\}\times \quad (11.6)
$$

$$
\frac{b_1\left(a_2-\dfrac{c}{1-r}\right)-k\left(a_1-\dfrac{c}{1-r}\right)}{2b_1b_2-2k^2}
$$

3.2 Comparison across scenarios

While solving the market equilibria in the second stage Cournot competition is straightforward, the preferences over the scenarios by the ports and terminal operators are not clear cut. There are many complicating factors such as the market sizes and quality differentials of the two ports (measured by parameters a_1 , a_2), shipping lines' sensitivity to terminal charges (measured by parameters b_1 , b_2) and the substitutability of the services offered in the two ports (measured by parameter *k*). Therefore, it is difficult to compare the ports and terminal operators' profits across scenarios. Nevertheless, following Proposition 1 can be obtained:

Proposition 1. For a terminal operator, to monopoly all the four terminals in the two ports is always the most preferred scenario. The total profits attributable to terminal operators are maximized in such a monopoly case. Mathematically, it implies that

$\pi^{3x} \geq Max\{\pi^{1x}+\pi^{1y}, \quad \pi^{2x}+\pi^{2y}, \quad \pi^{4x}+\pi^{4y}\}$, where the numbers in the superscripts denote the scenario number defined in Section 2.

Proof. For Scenario 1, $\pi^{1x}+\pi^{1y}=[(1-r)P_1-c](q_1^{1x}+q_1^{1y})+[(1-r)P_2-c](q_2^{1x}+q_2^{1y})$. Clearly, $(q_1^{3x}, \quad q_2^{3x})=(q_1^{1x}+q_1^{1y}, \quad q_2^{1x}+q_2^{1y})$ is a feasible point for Scenario 3, and $\pi^{3x}=\pi^{1x}+\pi^{1y}$ at this point since prices P_1 and P_2 are the same in these two scenarios at this point. Thus, the maximum profit in Scenario 3 should not be less than $\pi^{1x}+\pi^{1y}$.

For Scenario 2, $\pi^{2x}+\pi^{2y}=[(1-r)P_1-c]\cdot q_1^{2x}+[(1-r)P_2-c]\cdot q_2^{2y}$. Let $(q_1^{3x}, \quad q_2^{3x})=(q_1^{2x}, \quad q_2^{2y})$, which is a feasible point for Scenario 3. Along the same way as the previous argument, we have $\pi^{3x} \geq \pi^{2x}+\pi^{2y}$.

For Scenario 4, $\pi^{4x}+\pi^{4y}=[(1-r)P_1-c]q_1^{4x}+[(1-r)P_1-c]q_1^{4y}+[(1-r)P_2-c]q_2^{4y}$. Suppose $(q_1^{3x}, \quad q_2^{3x})=(q_1^{4x}+q_1^{4y}, \quad q_2^{4y})$ and by the same argument, we have $\pi^{3x} \geq \pi^{4x}+\pi^{4y}$.

Q.E.D.

This is not a surprising result. Monopoly over terminal operations in a region will eliminate both inter and intra port competitions. This would allow the terminal operator to achieve large monopoly profit, even though a proportion of its revenue will be paid to the port authorities. The preferences of the ports are nevertheless unclear. The revenues received by port authorities are proportional to the terminal operators' revenue in their respective ports. Unlike the terminal operator, however, port authorities do not incur any operation costs. Therefore, they may prefer a higher traffic volume than the monopoly terminal operator does. Clearly, an effective way to increase traffic volume is to introduce more competition. This explains the ownership patterns as shown in Table 1: virtually all Chinese ports have awarded concessions to multiple terminal operators. While the Hutchison Port Holdings has long established major presence in the Yangtze River Delta, such as at the Ningbo-Zhoushan port and the nearby competing Shanghai Port, recently the Ningbo-Zhoushan port has awarded the Modern Terminals concession right, which will enhance overall competition status. Such an intuition is formalized with following Proposition 2:

Proposition 2. When the proportion *r* of revenues allocated to port operators is sufficiently large, the port authorities prefer Scenario 1 to Scenario 3. Mathematically, this implies that $\prod_1{}^1 > \prod_1{}^3$ and $\prod_2{}^1 > \prod_2{}^3$, where the superscripts represent scenario number defined in Section 2. That is, when port authorities are able to charge terminal operators a significant proportion of their revenues, they prefer to introduce both intra and inter port competition to allowing one terminal operator to monopoly all terminals in the region.

Proof. Comparing the ports' profits directly, it can be shown that if the terminal operators' outputs in all cases are positive so that $a_1b_2-a_2k-\frac{c(b_2-k)}{1-r}$, then $\prod_1{}^1 > \prod_1{}^3$ so long as $7c>(1-r)a_1$, and otherwise $\prod_1{}^1 \leq \prod_1{}^3$. Similarly, $\prod_2{}^1 > \prod_2{}^3$ provided that $7c>(1-r)a_2$, and otherwise $\prod_2{}^1 \leq \prod_2{}^3$. Clearly, when *r* is sufficiently large, the conditions $7c>(1-r)a_1$ and $7c>(1-r)a_2$ always hold.

Q.E.D.

In this study, *r* is assumed to be exogenously determined. In reality, port authorities are more likely to charge a higher *r* when they have more bargaining power than terminal operators. Such bargaining power can be endowed within regulations. But more likely, and frequently, a port authority's bargaining power comes from its market power. For example, since Shanghai is a major trade hub port in mainland China, the Port of Shanghai is likely to have substantial bargaining power over shipping lines. This would allow the Port of Shanghai to share a high proportion of the terminal operators' revenue (or equivalently, a high price for terminal concession). If this revenue proportion is sufficiently high (in the sense that $7c > (1-r)a_1$ and $7c > (1-r)a_2$ as in our model), our modelling result indicates that the Port of Shanghai would prefer to award the terminal concessions to different terminal operators. This is indeed the case: when the shipping volume of Port of Shanghai was low, the port authority had worked closely, and mostly, with one single operator HPH. However, with the fast expansion and growing importance of Shanghai as a leading port, the Port of Shanghai has chosen to work with several operators including PSA and the Merchants group in building the mega size terminals in the Yangshan Island of Shanghai.

Due to the numerous factors considered in our model (e.g. relative market sizes and qualities of the two ports, price sensitivity of the shipping lines and service substitutability between the services offered in the two ports), it is difficult to obtain additional conclusions in the general model set up. In order to focus on the effects of intra and inter port competitions, therefore, we impose an additional assumption that the two ports are also symmetric to each other in the sense that $a_1 = a_2$ and $b_1 = b_2$. This leads to the following Proposition 3:

Proposition 3. When the two ports are symmetric but do not provide perfectly substitutable services, profit of a terminal operator, say *x*, decreases in the following sequence: *(xx,xx)* $\succ$ *(xy,xx)* $\succ$ *(xx,yy)* $\succ$ *(xy,xy)* $\succ$ *(xy,yy)*.

Proof. Operator *x*'s preference to *(xx,xx)* is directly obtained from Proposition 1. When the two ports are symmetric thus that $a_1 = a_2$ and $b_1 = b_2 = b$, it can be shown that $\pi^{4x} \le \pi^{1x}$ and $\pi^{1x} \le \pi^{2x}$ will hold so long as $b \ge k$, with the equality holds if and only if $b = k$. With symmetry between the two terminal operators, terminal operator *x*'s profits can be ranked directly across all above outcomes. Clearly, $b = k$ corresponds to the situation where the services provided in the two ports are perfectly substitutable or homogenous. If this is not the case, then the above profits rankings will be strict.

Q.E.D.

Basically, Proposition 3 indicates that a terminal operator's profit increases with its market power in the region. As a result, a terminal operator always prefers to control more terminals. *Ceteris Paribus*, a terminal operator can increase its profit by expanding its operation into the nearby ports (in our model, for operator *x* the preference follows *(xy,xx)* $\succ$ *(yy,xx))*. However, when all terminal operators in the region adopt such a strategy, they will be worse off (in our model, *(xx,yy)* $\succ$ *(xy,xy))*. This is similar to the classic prisoners' dilemma. Terminal operators would be better off if they could simultaneously stay off their competitors' territory, although expansion in the region is the dominant strategy. The Port of Hong Kong has long been served with multiple terminal operators. It is of these terminal operator's interests to expand to the nearby Port of Shenzhen. This explains HPH's investments in the Yantian Terminal. With such a strategy, HPH's profit will increase at the expenses of other terminal operators in Hong Kong. However, if there is sufficient traffic (the size of demand is at least twice of the Minimum Efficient Scale as assumed in our model), it is of other terminal operators' interests to also invest in the Port of Shenzhen. As a result, there will be both inter and intra port competitions in the region, leading to reduced terminal operators' profits. It should be noted that our model also suggest that when a port has increasing market power such that it can share a high proportion of terminal revenues (or charge a high price for the right of concession), it is of the port authority's interests to introduce more competition. That explains the strategies adopted by the Port of Shanghai and the Port of Shenzhen. Both ports were working closely with a single operator, namely HPH, in the initial development phase. However, as they gains more market power in the region, they introduced intra port competition by awarding terminal concessions to operators other than HPH. The situation is different for PSA, who is not only the sole terminal operator but also the practical port authority for the Port of Singapore. In such a case, it is of PSA's interests to expand to the nearby ports in Malaysia (e.g., Port of Tanjung Pelepas), but it is not of the interests of PSA, from the perspective of a terminal operator, to award concession rights in the port of Singapore to other terminal operators.

Our model suggests that terminal operators have incentive to expand their operations thus to gain market power. However, if all terminal operators follow this strategy, they may be trapped in a prisoners' dilemma. Therefore, terminal operators would be better off if they could work jointly to reduce competition. While such coordination is difficult during a period of fast market expansion, terminal operators may be forced to cooperate during market down turn in order to survive. The recent financial tsunami has shown a direct impact on the maritime trade, causing sharp decline in traffic volume. In China, several container terminals in the Tianjin Port are being integrated so that a unified terminal operator can better survive in the weak shipping market.

4. DISCUSSION AND CONCLUSIONS

Terminal concessions in seaports have recently attracted some academic attention. These studies have focused mainly on concession procedures and processes, including the determination of the concession term and concession fees, the inclusion of special clauses, concession site selection, division of risks and investment, performance target etc. While competition has been identified as an important consideration in concession awarding, no clear-cut conclusions have been obtained concerning its conditions and effects. Most studies on inter and intra port competitions have analyzed implications on economic efficiency, port choice and market share division. No modelling framework is available with which the effects of competition on seaports terminal awarding can be investigated. This also prevents researchers from explaining different strategies adopted by ports and terminal operators around the world.

To fill this gap in marine research, this study proposes a non-cooperative game theory model, where two terminal operators apply for terminal concessions in two adjacent ports. Some interesting results are obtained, which could potentially explain some observed practices in the marine industry. For example, the model suggests that a terminal operator's profits increases with its market power in the region. As a result, it always prefers to control more terminals. *Ceteris Paribus*, a terminal operator can increase its profit by expanding its operation into nearby ports. This implies that terminal operators such as HPH would have incentive to control more terminals both within Hong Kong and the adjacent Shenzhen port. Nevertheless, when all terminal operators have expanded their operations to every competing port in the region, they will be worse off due to an increase of inter and intra port competitions. This is similar to the classic prisoners' dilemma. Terminal operators would be better off if they could simultaneously stay off their competitors' territory, although expansion in the region is the dominant strategy. This implies that from the perspective of a terminal operator, PSA would prefer to control terminals in the nearby Malaysian ports without allowing other terminal operators into the Port of Singapore. If this is not possible due to reciprocal unfairness, then terminal operators in Singapore and Malaysia would be better off if they could simultaneously stay off their competitors' home ports.

Our modelling results also suggest that the preferences of port authorities over inter and intra port competitions are influenced by factors such as service differentiation among competing ports, market size and service quality differentials etc. In general, when a port authority has significant market power and thus it can charge a high price, or share a large proportion of its terminal operators' revenue, the port authority would prefer to introduce inter and intra port competitions, rather than allowing one terminal operator to monopoly all terminals in the region. Intuitively, when a port authority can gain most from traffic increases, it has incentive to stimulate traffic volume by introducing more competition in the terminal operation market. This explains the behaviours of fast growing ports such as Shenzhen and Shanghai. Although they have been mostly working with HPH in the early days, their increasing market power and importance in the region allow these port authorities to charge a higher price for concession rights, or to share a higher proportion of its terminal operators' revenue. This in turn brings incentives to introduce intra port competition. This explains why the Port of Shanghai and the Port of Shenzhen have chosen to work with terminal operators other than HPH in the recent expansion projects. The real cases illustrate the findings of our model.

While we have studied the preferences of ports and terminal operators respectively, we have not studied the combined impacts to these two groups and the overall port industry. In addition, one major benefit of economic modelling is that researchers can focus on the effects of particular issues (e.g. intra and inter port competition in our paper). However, such benefits come at a price: some moderating factors have to be abstracted away in the model for tractability consideration. In addition to competition, there are many other influencing factors in the terminal awarding process as identified in previous studies. To fully explain and model the practices observed in the maritime industry, both theoretical and empirical investigations are needed. We hope this paper could lead to more future studies on this important issue.

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27. Note if neither congestion nor service quality is considered, then any fixed payments on capacity or infrastructure investment will not affect the outputs by the terminal operators.

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