Vertical Integration and its Implications to Port Expansion

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Abstract

Over the years many shipping lines have established terminal operation companies, with some set up as independent firms. However, port authorities and local governments have not always welcomed external investment and control with open arms. The economic implications and each stakeholder's best strategies remain unclear. This study develops an analytical model in order to study the effects of vertical integration, with a focus on shipping lines' investment in ports' capacity. Modelling results suggest that vertical integration between terminal operator and a shipping line leads to higher port capacity, port charge, market output and consumer surplus. It also reduces delay costs. All these results suggest that vertical integration can be an important source of synergy for the maritime industry. However, vertical integration increases the participating carrier's output at the expenses of non-integrating rival shipping firms. The overall social welfare change is uncertain and influenced by capital costs. Therefore, port authorities and government regulators should carefully review the market competition status as well as port expansion plans.

Key words: port and shipping lines; capacity investment; vertical integration.

1. Introduction

The shipping industry has experienced significant changes in recent years, demonstrating a notable trend in which shipping companies are increasingly involved in port management and terminal operation (Drewry, 2017). Shipping lines' investment in ever-larger vessels calls for the corresponding upgrade of port facilities. This is a challenging task and there have been some massive delays at major ports. For example, Shanghai's average delay time was estimated to be above 50 hours in May 2017 (Reuters, 2017). Port and terminal operators face the challenge to secure large capital investments so that to handle large vessels and increased traffic volumes in an efficient and timely manner (Drewry, 2016a).

Drewry (2016b) argued that marine ports were stepping into a mature market, with demand growth estimated to be below 3% until 2020. Terminal investments by shipping lines may be a promising way to solve the dilemma of slow market growth versus the need for port upgrade and expansion. Indeed, many shipping lines have established terminal operation companies, with some set up as independent firms. As shown in Table 1, eight out of ten of the world biggest carriers have terminals under (or partly under) their operation and most of the carriers have their related terminal operation companies. Some of them, such as APM-Maersk, MSC, CMA CGM and COSCO, have established terminal operation companies that also provide services to other carriers. Other carriers, such as Evergreen Line, Yang Ming, NYK and MOL, offer public services in their "home court" (i.e., Taiwan and Japan) and operate dedicated terminals as gateways to other regions (e.g., Yang Ming in Long Beach). Figure 1 reports profitability and throughput of the world's top six container terminal operators, which jointly account for approximately 30% of the global TEU throughput. Even some of these top operators, such as APM and COSCO, are affiliated with shipping lines.

<Table1 and Figure 1 about here>

The most common way that shipping lines engage in terminal operation is by signing a leasing agreement or through port concession, after which a professional operator (which can be related to a shipping line) takes over the management of the port but not the capital assets. Most modern container terminals follow the concession agreement model, often with joint ventures formed with a mixture of financial investors, shipping lines, terminal operators, construction companies and local interests (Botham, 2014; Yip et al., 2014).

The performance of ports and terminals is also pivotal to the overall performance of the container shipping sector. Ports must not only ensure sufficient capacity, but must also achieve high productivity and service levels in terminal development. Many port authorities, the governing body of ports, thus try to secure long-term commitment from customers and cooperate with global terminal/port operators to achieve increasingly sophisticated operational standards. Terminal operators therefore play a very important role in the port community and the liner shipping industry.

However, port authorities and local governments have not always welcomed external investment and control with open arms. For example, COSCO encountered substantial opposition from both the Greek government and other European stakeholders when bidding for the concession of the Port of Piraeus in Greece. The maritime industry and government policymakers around the world have yet to reach a consensus on the effects of and best approaches to such an industry trend. Despite an increasing amount of vertical integration between terminals and private players, such as shipping lines, few studies have systematically evaluated such an important issue. The economic implications and each stakeholder's best strategies remain unclear.

This study aims to fill this gap between theory and practice by analytically modelling the arrangements between ports and shipping lines. The study aim to achieve two major objectives. The first objective is to develop an analytical model with a focus on shipping lines' investment in ports' capacity, as many shipping lines have taken part in port management as shareholders through joint ventures with these ports' terminal operators. The second objective is to identify the effects of vertical integration on different players in the maritime transport industry and on social welfare. With a better identification of the pros and cons of carriers' involvement in terminal operation, our study facilitates decision making for both industry players and government policymakers, and other stakeholders in the port community (Lam, Ng and Fu 2013).

The remainder of this paper is organised as follows. The second section provides a literature review. Section 3 and Section 4 present the basic economic model and the scenario with vertical integration, respectively. Summary and conclusions are provided in the last section.

2. Literature Review

Vertical integration is a well-studied topic in economics, especially in the industrial organisation literature. Riordan (2008) concluded that vertical integration can help an integrated company extract more monopoly profit and bargaining power. However, such a result does not always hold when downstream companies are not highly concentrated and have no bargaining power (Mathewson and Winter, 1984). Rey and Tirole (2007) concluded that vertical integration helps upstream companies restore their market power, especially when the integrated company can treat its own downstream affiliate favourably to enhance its competitiveness. Both unintegrated companies and social welfare are however harmed. Another important finding is that vertical integration can often eliminate mark-ups, or double marginalisation. If the upstream monopolist can vertically integrate with a downstream company, total profits can be increased and consumers can benefit from the removal of double marginalisation (Spengler, 1950). In this sense, vertical integration reduces market competition but may improve welfare. Other studies argued that vertical integration can be used to increase rivals' costs. This strategy would harm the integrated firm's rivals by pushing them out of the market or reducing their production. Although consumer interest is undermined, eliminating inefficient producers may enhance overall economic efficiency. Furthermore, when a firm's efficiency is improved by vertical integration, downstream companies' price incentives also change (Chen, 2001). Overall, these theoretical studies suggest that the effects of vertical integration can be complex and dependent on market structure.

A number of studies have investigated vertical integration in the maritime industry, mostly based on qualitative and descriptive analysis. Casson (1986) emphasised the incentives for shipping lines to invest in terminal operation businesses which include dockside equipment and well-trained labour force. Midoro, Musso, and Parola (2005) indicated that investing in ports could help carriers better satisfy shippers' needs for efficiency and reliability, improve the control of freight and reduce costs. In addition, integrating with terminal operators can help shipping lines reduce their risks (Notteboom & Rodrigue, 2012) and meet their ever-larger infrastructural requirements for terminals (van de Voorde & Vanelslander, 2009). Vertical integration with private sectors can help port authorities obtain more investment to accommodate traffic volume growth, infrastructural requirements and financial risks (Lun, Lai, & Cheng, 2010; Notteboom & Rodrigue, 2009; Psaraftis & Pallis, 2012). Meanwhile, terminal operators can enhance their global competitiveness by increasing their business scale (Lee & Meng, 2014, p. 481) and strengthening their negotiation power against shipping lines (Lee & Song, 2014, p. 48).

The use of dedicated terminals is one popular integration mode. Turner (2000) examined how terminal-leasing policy affected throughput and productivity. Using real data from the Port of Seattle in 1996, Turner (2000) estimated that by converting all six dedicated terminals into public multi-user terminals, the port could keep its original throughput volume with shorter operation time. Haralambides, Cariou, and Benacchio (2002) found that carriers with enough power to own dedicated terminals would benefit from such arrangements, as they could enjoy shorter queuing times. Asgari, Farahani, and Goh (2013) and Kaselimi, Notteboom, and De Borger (2011) developed analytical models, with which different scenarios were considered and compared with real data. Kaselimi et al. (2011) discussed the influences of dedicated terminals from the perspectives of terminal operators and port authorities. Terminal operators are not negatively affected by introducing dedicated terminals either in the ports they operate or in competing ports, as they can increase their prices and capacities. Shipping lines that do not have their own dedicated terminals and that can only use public ones, however, lose due to higher port dues. Asgari et al. (2013) investigated the competition and cooperation strategies of two competing ports and their shipping lines. They found that in the short term, ports should adopt dynamic pricing strategies based on their competitors' port dues, and that in the medium and long term it was advisable to form strategic alliances with shipping lines and other ports to gain more market share and profit. They used an analytical model in which shipping lines first decide their routes and then ports decide their charges. The cooperation between shipping lines and ports is modelled as a multi-objective decision-making process.

Álvarez-SanJaime, Cantos-Sánchez, Moner-Colonques, and Sempere-Monerris (2013) categorised different ways of using carriers' own terminals. They found that carriers should operate their own terminals non-exclusively to pursue higher profits. Carriers not owning terminals may also be better off with non-exclusive terminals, as the use of different terminals allows product differentiation in the market. Such an arrangement may also result in higher port dues, social welfare, industry profits and user surplus. Similar to shipping lines, terminal operators and port authorities are also trying to integrate with different partners and taking on more active roles (Rodrigue & Notteboom, 2009). For example, container terminal operators in Europe have integrated with feeder service providers and inland terminals (Notteboom, 2002). De Borger and De Bruyne (2011) studied the effects of vertical integration between terminal operators and truck companies. The government has incentives to promote competition between downstream companies, and vertical integration in the logistic chain is beneficial to social welfare. Overall, studies in the maritime industry suggest that vertical integration could benefit the integrated port-carrier in terms of profit and productivity, but the implications to welfare and competition can be ambiguous.

Vertical integration has also been studied in other transport sectors. Fu, Homsombat, and Oum (2011) reviewed different airport-airline arrangements, and concluded that such vertical cooperation can benefit the local economy and consumers. However, such a practice can strengthen an airline's monopoly power in its allied airport, thereby harming competition. Airport-airline collusion has been studied by Barbot (2009), Barbot, D'Alfonso, Malighetti, and Redondi (2013), D'Alfonso and Nastasi (2012, 2014). In general, they found vertical collusion and integration strengthen participating firms' profit, whereas the competition and welfare effects can be mixed. Another stream of literature analysed revenue sharing between airlines and airports (Zhang, Fu, and Yang 2010; Fu and Zhang 2010; Saraswati and Hanaoka 2014; Yang, Zhang, and Fu 2015). Consistent with previous studies, they identified both benefits of vertical cooperation as well as potential competition concerns. Wang, Zhuo, and Niu (2017) focused on the vertical integration between airlines and airports in freight transport, and identified either a win-win or lose-lose situation may emerge.

In the rail sector, Preston (1996) argued that vertical integration might be a good way of achieving economies of scope. Ferreira (1997) recommended a joint-venture relation between infrastructure operator and dominant rail service provider. Growitsch and Wetzel (2009) concluded that vertical separation may benefit integrated companies but undermine the industry's efficiency.

In summary, studies on vertical integration suggested both positive and negative effects. Although most studies suggested beneficial outcome to the integrated company, the implications to the non-integrated companies, the entire market and customers tend to be mixed and dependent on market structures. Besides, other than Xiao, Fu, and Zhang (2013) who found a positive effect on airport capacity investment, few studies have investigated the effects of vertical integration on transport infrastructure investments [1]. Therefore, to understand the effects of vertical integration in the maritime industry, it is important to conduct a comprehensive analysis taking the industrial characteristics into consideration. The following section introduce the basic economic model developed for such an investigation.

3. The Basic Model

In this section, we consider the case when there is one (private) profit-maximizing container terminal operating in a port governed by a public port authority. A dynamic game model is developed to examine the optimal decisions of key stakeholders including the shipping firms, the terminal operator and the port authority. The basic model can be used as a benchmark so that the case of vertical integration, analyzed in the next section, can be compared and evaluated.

3.1 Model setup

Following the approach used in previous studies (Luo et al. 2010; Xiao et al. 2012; Wang et al. 2012, Zhuang, Luo, & Fu, 2014), it is considered that the terminal operator has constant marginal cost per container c, and sets a per container port charge f that is collected from the N shipping firms calling the port. It is assumed that the N carriers are symmetric in the sense

[1] Although Xiao et al. (2016) concluded that vertical integration can lead to increased airport capacity, their model considered possible savings in capital costs due to airport revenue bonds and thus may not be directly applicable to the maritime sector.

that they provide homogeneous services and have identical marginal cost which are normalised to zero. The inverse demand function for shipping service is specified as follows:

$$p = a - b \cdot Q \quad (1)$$

The output of carrier i is denoted as q_i and hence the total market output, or the port throughput, is calculated as $Q \equiv \sum_{i=1}^{N} q_i$. Carriers may incur costs of port delay d from extra expenditure on fuel, crew and other operations during congestion and delay. It is assumed that cost of delay depends on the terminal's capacity and throughput as follows:

$$d = \gamma \frac{Q}{k} \quad (2)$$

where k is the capacity of the terminal and γ is a parameter reflecting the effects of congestion on carriers' costs per container.[2]

In addition to shipping lines and terminal operators, we also consider the decision of a port authority. Such a port authority – terminal operator – shipping lines structure may be most relevant for ports that adopt a "landlord port model". Depending on specific markets considered, a port authority may have alternative objectives aiming for profit, revenue, traffic volume, local economy etc.[3] On the one hand, many ports remain controlled and owned by local governments, either directly through public port authorities or indirectly through state-controlled corporations. The public ownership implies that social welfare shall be a key consideration of the decision-maker. On the other hand, many ports have been fully or partially privatized or corporatized. In these cases, the port authority is only involved in non-commercial issues such as environment and safety issues. In other cases, port authority is not an independent decision maker, or its objective may be regarded as the same as the terminal to maximize profit. To develop a framework that is general enough to cover all these cases, following (Yang and Zhang HSR study), we model the port authority as maximizing a weighted sum of (local) welfare and profit, i.e., $\theta \cdot SW + (1-\theta)\Pi$, where $0 \le \theta \le 1$. Clearly, when $\theta = 1$ this specification corresponds to the case when a public port aims to maximize social welfare, whereas when $\theta = 0$ the port authority behaves purely as a profit-maximizer, which corresponds to the case when the whole port is completely privatized and is free to set its charges and capacity (i.e. equivalent to the case in which the port authority is not an independent decision maker or has the same objective function as the terminal).

The existing port capacity is denoted as k_0. The port authority may demand an expansion thus that extra capacity Δk will be invested by the terminal operator. The usable port capacity is therefore $k = \Delta k + k_0$. The capital cost per unit capacity is r, and thus the investment cost of the terminal operator is $r\Delta k$. In practice, although port authorities in ports

[2] In practice, due to economies of scale effects the delay cost per container should decrease with ship size. For mathematically tractability, and because ship size is not explicitly modelled, a simple specification is used.

[3] Different assumptions have been used in the transport literature which are not always consistent. For example, although welfare maximization has been routinely used in models developed for (public) airports (Zhang and Zhang 2003, 2006, 2010; Fu and Zhang 2010; Xiao et al. 2013, 2017; Yang and Fu 2015), no census has been reached in the maritime industry with respect to the most appropriate objective function for port authorities. This has led to some inconsistency since in a few US cities, the port authority control and manage both airports and ports in their region (e.g. the port the Port Authority of New York and New Jersey, Massachusetts Port Authority, Port of Oakland, Port of Seattle)

that follow the landlord port model often have significant power in determining future port plans, capacity investments are usually negotiated or jointly decided by the port authority and terminal operator. In many cases, concession fees may need to be adjusted in response to capacity investment plans. For modelling tractability and clarity, the port authority is assumed to be able to unilaterally decide capacity expansion. A concession fee is a transfer between terminal operator and port authority that has little effect on social welfare and therefore is not explicitly considered in the model. Mathematically, if the concession fee is a pre-agreed fixed amount, it would not affect the port authority and terminal operator's decisions considered in the model.

The behaviour of the port authority, terminal operator and shipping firms is analyzed in the following multi-stage model:

- In Stage 1, the port authority mandates extra capacity to be invested by the terminal operator, denoted as Δk. The capital cost is therefore $r\Delta k$.
- In Stage 2, with capacity $k = \Delta k + k_0$ and constant marginal cost c, the terminal operator sets a port charge f per container.
- In Stage 3, the carriers compete in quantity to maximise their individual profits. The port throughput is $Q \equiv \sum_{i=1}^{N} q_i$ and the cost of delay per container is $\gamma \frac{Q}{k}$.

The market structure and each organisation's key decision variables in the base scenario are depicted in Figure 2.

<Figure 2 about here>

Because the carriers' operation costs are normalized to 0, carrier i's objective function can be specified as follows:

$$\max_{q_i} \pi_i = q_i \cdot \left[p(Q) - f - \gamma \frac{Q}{k}\right] \quad (3)$$

The terminal operator aims to maximise its profit and thus its objective function can be specified as follows:

$$\max_{f} \Pi_T = Q \cdot (f - c) - \Delta k \cdot r \quad (4)$$

To model the port authority's objective, note social welfare is the sum of the terminal's profit and consumer surplus, i.e., $SW = CS + \Pi_T$, where consumer surplus is specified as $CS = \int_0^Q p(x)dx - p(Q) \cdot Q$. As in most cases container carriers are overseas companies, it is assumed that the port authority does not take carriers' profits into account unless a carrier is fully integrated with the local port. That is, we consider the case when the port authority aims to maximise local social welfare only, which includes consumer surplus and the terminal operator's profit. The port authority's objective function is expressed as:

$$\max_{\Delta k} W = \theta \cdot SW + (1 - \theta)\Pi_T = \theta \cdot CS + \Pi_T \quad (5)$$

3.2 Model analysis

From (3), we know the first-order condition (FOC) of carrier i's profit maximization is

$$\mathrm{p(Q)} - \mathrm{f} - \gamma\frac{\mathrm{Q}}{\mathrm{k}} + \mathrm{q_i}\left(\frac{\partial \mathrm{p}}{\partial \mathrm{Q}} - \frac{\gamma}{\mathrm{k}}\right) = 0 \tag{6}$$

Rearranging (6) and using the symmetry of the carriers, we have

$$\mathrm{q}_{i,B} = \frac{(a-f)}{(N+1)(b+\gamma/\mathrm{k})} \tag{7}$$

$$\mathrm{Q}_B = \frac{N(a-f)}{(N+1)(b+\gamma/\mathrm{k})} \tag{8}$$

where the subscript B indicates the basic model. Next, we analyse the terminal operator's decision. The FOC of maximizing (4) is

$$\frac{\partial \mathrm{Q}}{\partial f}(\mathrm{f} - \mathrm{c}) + \mathrm{Q} = 0 \tag{9}$$

From (8) and (9), we have

$$f_B = (a + c)/2 \tag{10}$$

Substituting (10) into (7) and (8), we have

$$\mathrm{q}_{i,B} = \frac{a-c}{2(N+1)(b+\gamma/\mathrm{k}_B)} \tag{11}$$

$$\mathrm{Q}_B = \frac{N(a-c)}{2(N+1)(b+\gamma/\mathrm{k}_B)} \tag{12}$$

Utilizing the analytical solutions, it is clear that when carriers and the terminal operator operate independently, the port capacity has a positive effect on market output. That is, port throughput increases with port capacity. This is intuitive as increased port capacity reduces port congestion and delay, and therefore carriers' costs.

To investigate the port authority's port expansion decision, note substituting (10) and (12) into the port authority's objective function (5), we obtain its FOC as

$$\theta\left(-\frac{\partial \mathrm{p}}{\partial Q}\cdot\frac{\partial \mathrm{Q}}{\partial k}\cdot \mathrm{Q}\right) + \frac{\partial \mathrm{Q}}{\partial k}(\mathrm{f} - \mathrm{c}) + \mathrm{Q}\frac{\partial \mathrm{f}}{\partial k} = \mathrm{r} \tag{13}$$

The terms in the first bracket in the LHS of (13) means the marginal contribution of the port capacity expansion to consumer welfare, while the second term and the third term in the LHS of (13) are the marginal contribution of the port capacity expansion to the terminal operator's profit. Therefore, in the optimum the weighted marginal contribution of the port capacity expansion should be equal to its marginal cost r. Using (1) and (10), we can simplify (13) as

$$\theta\left(\frac{\partial \mathrm{Q}}{\partial k}\cdot \mathrm{bQ}\right) + \frac{\partial \mathrm{Q}}{\partial k}(\mathrm{f} - \mathrm{c}) = \mathrm{r} \tag{14}$$

which determines the optimal capacity investment Δk.

4. Vertical Integration

To model the effects of vertical integration, we consider the case when carrier i form a vertical integration arrangement in which the carrier invests in the terminal expansion and shares terminal revenue proportional to its investment. Such an approach may reflect the joint venture arrangements in the maritime industry, in which a carrier forms a new company jointly with a local company or operator to build and operate a new terminal. For example, Port of Shanghai's Waigaoqiao Phase-4 Terminal is operated by a joint venture established by Shanghai International Port Group Co., Ltd. and APM Terminals, the sister company of Maersk.

4.1 Model setup

Consistent with the base case, the case of vertical integration is analyzed with the following multi-stage game:

- In Stage 1, the port authority decides capacity expansion Δk, given the share that the carrier i can invest in the capacity expansion s.
- In Stage 2, terminal operator decides port charge f.
- In Stage 3, carrier i, j decide their outputs q_i, q_j.

In order to simplify the problem, here we assume that the carrier i's investment share s is a pre-determined parameter. An alternative specification may treat s as a decision variable determined by the port authority or the terminal operator, possibly through bargaining or take-it-or-leave-it contract negotiation. This can be left for future studies. The market structure and decision-making is presented as in Figure 3.

<Figure 3>

Consider that carrier i now has the opportunity to invest a share (s) into terminal's extra capacity Δk. In return, terminal A would share its profit in the proportion of $\frac{s\Delta k}{k_A}$ with carrier i. With such an arrangement, this carrier's goal is hence:

$$\max_{q_i} \pi_i = q_i \cdot \left[p(Q) - f - \gamma \frac{Q}{k}\right] + \frac{s\Delta k}{k} \cdot [Q \cdot (f - c)] - s \cdot \Delta k \cdot r \tag{15}$$

The first part of the right-hand side is the profit from liner shipping services whereas the second part is the profit shared from the terminal investment. Other carriers aim to achieve the following:

$$\max_{q_j} \pi_j = q_j \cdot \ [p(Q) - f - \gamma \frac{Q}{k}] \tag{16}$$

The terminal's objective is expressed as follows:

$$\max_{f} \Pi_T = \frac{k - s\Delta k}{k} \cdot Q \cdot (f - c) - (1 - s) \cdot \Delta k \cdot r \tag{17}$$

where the subscript T denotes the terminal operator. Let $\Pi_J = Q(f - c) - \Delta k \cdot r$ be the integrated profit of the joint venture of the terminal operator and carrier I, where the subscript J means the joint venture. As defined earlier, the port authority's objective function is to maximize the weighted share of welfare and profit by deciding Δk and s. However, since we aim to consider local welfare only, only the profit kept by the terminal is considered by the port authority. Thus its objective function is specified as follows:

$$\max_{\Delta k} \mathrm{W} = \theta \cdot SW + (1-\theta)\Pi_J = \theta \cdot CS + \Pi_T \tag{18}$$

4.2 Model analysis

From (15), we know the FOC of carrier *i*'s profit maximization is

$$\mathrm{p(Q)} - \mathrm{f} - \gamma\frac{\mathrm{Q}}{\mathrm{k}} + \mathrm{q_i}\left(\frac{\partial \mathrm{p}}{\partial \mathrm{Q}} - \frac{\gamma}{\mathrm{k}}\right) + \frac{s\Delta k}{k}\cdot(f-c) = 0 \tag{19}$$

From (16), we know that carrier *j*'s FOC is

$$\mathrm{p(Q)} - \mathrm{f} - \gamma\frac{\mathrm{Q}}{\mathrm{k}} + \mathrm{q_j}\left(\frac{\partial \mathrm{p}}{\partial \mathrm{Q}} - \frac{\gamma}{\mathrm{k}}\right) = 0 \tag{20}$$

Rearranging (19) and (20), and using the symmetry of the other carriers except carrier *i*, we have

$$\mathrm{q}_{i,V} = \frac{(a-f)+(f-c)Ns\Delta k/k}{(N+1)(b+\gamma/\mathrm{k})} \tag{21}$$

$$\mathrm{q}_{j,V} = \frac{a-f-(f-c)s\Delta k/k}{(N+1)(b+\gamma/\mathrm{k})} \tag{22}$$

$$\mathrm{Q}_V = \frac{N(a-f)+s\Delta k(f-c)/k}{(N+1)(b+\gamma/\mathrm{k})} \tag{23}$$

where the subscript V indicates the case of vertical integration.

Next, we analyse the terminal operator's decision. The FOC of maximizing (17) is

$$\frac{\partial \mathrm{Q}}{\partial f}(\mathrm{f}-\mathrm{c}) + \mathrm{Q} = 0 \tag{24}$$

From (23) and (24), we have

$$f_V = \frac{N(a+c)-2cs\Delta k_V/k_V}{2(N-s\Delta k_V/k_V)} \tag{25}$$

Substituting (25) into (23), we have

$$\mathrm{Q}_V = \frac{N(a-c)}{2(N+1)(b+\gamma/\mathrm{k}_V)} \tag{26}$$

Comparing (25) to (10), we have the following proposition.

Proposition 1. *The vertical integration strategy leads to higher port charge so that* $f_V > f_B$.

Proof: It is easy to know that $\partial f_V/\partial N < 0$ and $\lim_{N\to\infty} f_V = (a+c)/2 = f_B$. Therefore, we have $f_V > f_B$. □

Moreover, examining the effect of carrier *i*'s investment share on port charge, we find $\frac{\partial f_V}{\partial s} = \frac{N(a-c)\Delta k/k}{2(N-s\Delta k/k)^2} > 0$, which leads to the following corollary.

Corollary 1. *As carrier i invests in a higher proportion of the terminal' capacity, the port charge will be higher.*

Next, we investigate the effect of vertical integration on carriers' outputs. By comparing (21) and (22), i.e., the output levels of the integrated carrier and the other non-integrated carriers, we have the following corollary.

Corollary 2. The integrated carrier has a higher output level than that of the non-integrated carriers.

The intuition for the results in the Proposition and Corollaries is as follows: with integration, the terminal operator and carrier *i* partially solves the problem of "double marginalization", which leads to increased output of carrier *i*. This also allows the terminal operator to increase its charge. Because the carriers are engaged in the Cournot competition and their outputs are substitutable, the higher port charge and carrier *i*'s increased output restrain rival competitors' output. Such effects become stronger as carrier *i* gets more involved (i.e. controls a larger share of the terminal's capacity and profit).

Finally, we examine the port authority's port expansion decision under the vertical integration. Substituting (25) and (26) into (18), the FOC can be obtained as follows.

$$\theta\left(\frac{\partial \mathrm{Q}_V}{\partial k_V}\cdot \mathrm{bQ}_V\right)+\frac{\partial \mathrm{Q}_V}{\partial k_V}(\mathrm{f}_V-\mathrm{c})+\mathrm{Q}_V\frac{\partial \mathrm{f}_V}{\partial \Delta k_V}=r \quad (27)$$

The economic meaning of (27) is similar to that of (14), and it determines the optimal port capacity expansion Δk_V under vertical integration. Comparing the port capacity expansion decisions between the basic model and the vertical integration model, i.e., Δk_B and Δk_V, the following proposition can be obtained.

Proposition 2. *The vertical integration strategy leads to larger port capacity thus that $\Delta k_V \geq \Delta k_B$. Moreover, more capacity is added as carrier i investments a larger share in the expansion project, i.e., $\partial \Delta k_V/\partial s > 0$.*

Proof: we need to compare $\Delta \mathrm{k}_\mathrm{B}$ determined by (14) and $\Delta \mathrm{k}_\mathrm{V}$ determined by (27). Note that the LHS of (14) has no relationship with the parameter *s*. The LHS of (27) has a positive relationship with *s*, because $\partial \mathrm{Q}_V/\partial s = 0$, $\partial^2 \mathrm{Q}_V/\partial k_V \partial s = 0$, $\partial \mathrm{f}_V/\partial s > 0$ and $\partial^2 \mathrm{f}_V/\partial \Delta k_V \partial s > 0$. When $s = 0$, the LHS of (14) equals to the LHS of (27), which leads to $\Delta k_V = \Delta k_B$. When $0 < s \leq 1$, the LHS of (14) is constant, whereas the LHS of (27) increases, if $\Delta k_V = \Delta k_B$. Thus, in order to keep both (14) and (27) hold simultaneously, $\Delta k_V \geq \Delta k_B$ must hold because $\partial^2 \mathrm{Q}_V/\partial {k_V}^2 < 0$. □

Because vertical integration promotes port capacity expansion, the following corollary can be obtained by comparing the outputs of the whole market under the base model and the vertical integration model.

Corollary 3. *Vertical integration leads to larger market outputs, i.e.,* $Q_V \geq Q_B$.

Proof: Because $\Delta k_V \geq \Delta k_B$, we have $k_V \geq k_B$. The comparison of (12) and (26) leads to $Q_V \geq Q_B$. □

Moreover, comparison of the delay costs under the base model and the vertical integration model leads to the following corollary.

Corollary 4. *The vertical integration reduces delay costs, i.e.,* $d_V \leq d_B$.

Proof: Because Q_V and Q_B have the same form: $Q = \frac{N(a-c)}{2(N+1)(b+\gamma/k)}$, we have $d = \frac{Q}{k} = \frac{N(a-c)}{2(N+1)(bk+\gamma)}$. Because $k_V \geq k_B$, we obtain $d_V \leq d_B$. □

In summary, the terminal operator's vertical integration with carrier *i* increases the port capacity and the port charge, promotes the whole market outputs, reduces delay costs, and raises the consumer surplus level. As there is full vertical integration between terminal operator and shipping lines, modelled as carrier *i* invests all port expansion, the port capacity, the port charge, the whole market outputs and the consumer surplus all reach the highest levels, whereas the delay costs become minimum. As carrier *i*'s share *s* increases, the vertical integration is strengthened. Thus, double marginalization problem is better internalized between the terminal operator and the carrier. This leads to higher port capacity and market outputs. However, the larger port expansion involve higher investment costs, which makes the comparison on the social welfare uncertain.

5. Summary and conclusions

The container liner shipping industry has experienced significant changes in recent years. Despite market growth over the past decades, shipping companies now face the market circumstance described as "low freight rates, low profitability, poor service levels, huge volatility and now more bankruptcies and loss of jobs" (Drewry, 2016a, p. 2). Major port terminal operators, in contrast, have managed to maintain solid balance sheets, although their profitability has declined amid market-wide depression. Investors' interest in port terminals has been increasing. A number of shipping firms also established their own subsidiaries and/or sister companies that specialized in port operations. Port and terminal operators also need to secure more capital investment so that to upgrade port facilities to serve ever-larger vessels. Terminal investments by shipping lines may be a promising way to solve the dilemma of slow market growth versus the need for port upgrade and expansion.

Although vertical integration has been an important issue in the economics literature, the implications for different stakeholders and social welfare are mixed and often dependent on market structure and industry characteristics. Although a number of studies have been carried out in various transport sectors, including maritime, aviation and railways, there is a need to analytically investigate the implications of vertical integration using a comprehensive model that characterizes the industry reality in the maritime sector.

This paper develops an economic model in which the decisions of port authority, terminal operator and shipping lines are considered in a multi-stage game. A general objective function of the port authority is specified so that a range of possible scenarios, such as profit-maximizing, welfare-maximizing and a combination of the two can be studied within one framework. Our modelling results suggest that the vertical integration between terminal operator and a shipping line leads to a higher port capacity, port charge, market output and consumer surplus. It also reduces delay costs. All these results suggest that the vertical integration can be an important source of synergy for the maritime industry. However, vertical integration increases the participating carrier's output at the expenses of non-integrating rival shipping firms. The overall social welfare change is also uncertain and influenced by capital costs. Therefore, port authorities and government regulators should carefully review the market competition status as well as port expansion plans.

Although the analytical model developed is quite comprehensive to consider important decisions of various stakeholders, due to mathematical tractability we were forced to make some simplifying assumptions such as linear demand and a particular forms of delay cost. It would be useful to examine alternative specifications in future studies. In addition, inter-terminal competition and inter-port competition are not explicitly modelled. These are useful extensions for future investigations, albeit beyond the scope of the current study.

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TABLE 1 WORLD TOP 10 SHIPPING LINES' RELATED TERMINAL OPERATORS

Shipping company (Market share)	*Terminal operator*	*Relation*	*Number of terminals*
APM-Maersk (16.7%)	APM Terminals	Both (Maersk Line and APM Terminals) are owned by The Maersk Group	73
Mediterranean Shg Co (14.5%)	Terminal Investment Limited (TIL)	Established fully by MSC	34
CMA CGM (11.7%)	Terminal Link	Capital is held by CMA CGM (51%) and China Merchants Holdings International (49%).	27
	CMA Terminals	Fully owned CMA CGM subsidiary	
COSCO Shipping Co Ltd (8.5%)	COSCO Shipping Ports	Both (COSCO Container Line and COSCO Shipping Ports) are owned by The COSCO Group	31
Hapag-Lloyd (7.1%)	N.A.	N.A.	N.A.
Evergreen Line (5.0%)	N.A.	N.A.	9 (Incomplete statistics)
OOCL (3.1%)	Two affiliate companies	Fully owned OOCL subsidiaries	2
Yang Ming Marine Transport Corp. (2.8%)	N.A.	N.A.	7
Hamburg Süd Group (2.6%)	N.A.	N.A.	N.A.
NYK Line (2.5%)	Ceres Terminals	Purchased in 2002	11
	Nippon Container Terminals	Established partly by NYK	
MOL (2.5%)	TraPac	Fully owned MOL subsidiary	10
	Joint ventures		

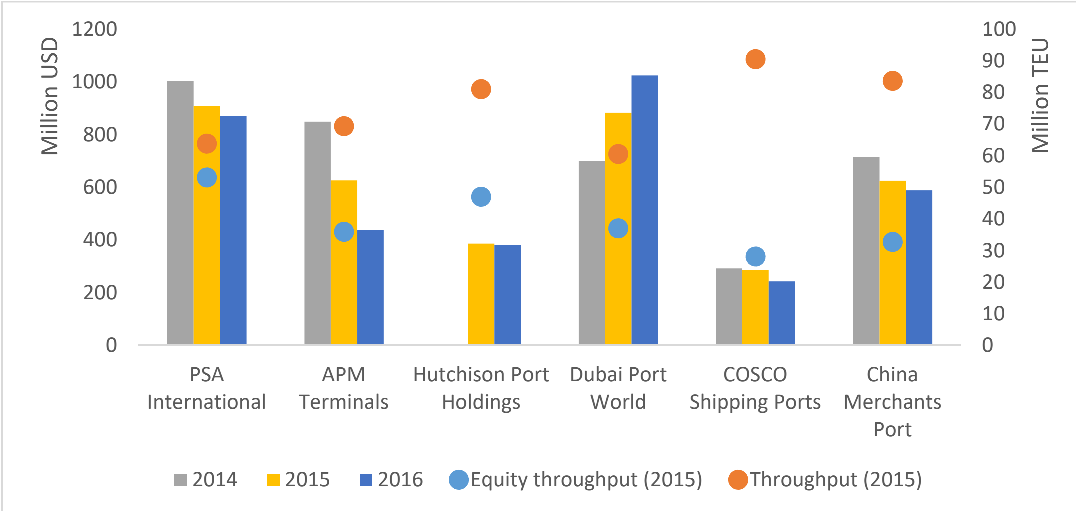

FIGURE 1 SIX INTERNATIONAL TERMINAL OPERATORS' PROFITS AND THROUGHPUT

Note: the left vertical axis reports terminal operators' profit whereas the right vertical axis reports the throughput. Equity throughput is calculated based on terminal operator's ownership shares in the terminal/port they invested.

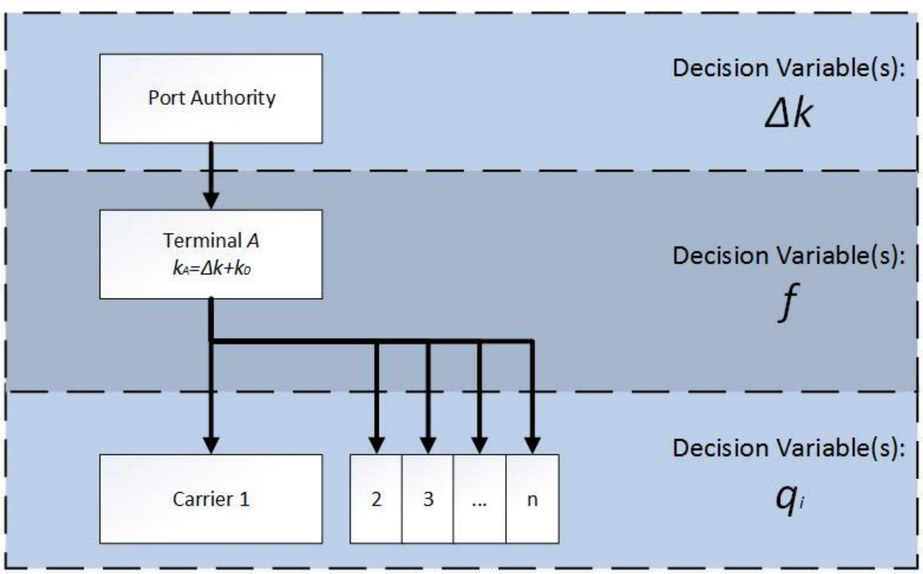

FIGURE 2 BASE SCENARIO OF THE MODEL

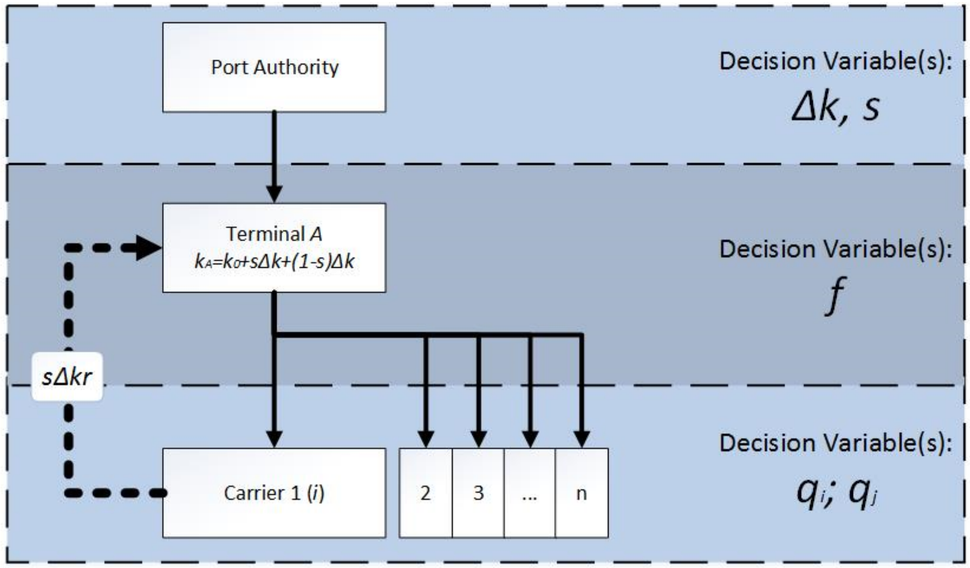

FIGURE 3 VERTICAL INTEGRATION THROUGH JOINT VENTURE