An Empirical Analysis for Container Ship Investment

Meifeng Luo[1*], *Lixian Fan*[2]

[1]Department of Logistics and Maritime Studies, The Hong Kong Polytechnic University, Hong Kong.
Email: lgtmluo@polyu.edu.hk

[2]Department of Logistics and Maritime Studies, The Hong Kong Polytechnic University, Hong Kong.
Email: lgtxfan@polyu.edu.hk

Abstract

Understanding capacity investment behavior can benefit both private business operation and public policy development in the container shipping industry. This study investigates how global container shipping companies with different sizes decide to expand their fleets in a competitive market, using both theoretical and empirical approaches. In the theoretical part, important factors in firms' capacity investment are identified for both operational needs and strategic market competition. In the empirical analysis, all the identified factors were tested using the observed data on ship investment for existing shipping firms. The results show that market demand, rather than the market price, are the main factors in capacity investment. While the investment of small firms is more sensitive to demand change, larger firms are more sensitive to the change in market share. Firms' investment will increase with the competitor's capacity investment in a booming market, but not when it is in recession. The time-charter index and newbuilding price are not important for shipping capacity investment.

Keywords: Container, Optimal investment, Strategy, Utilization rate

1. Introduction

Capacity investment is a critical decision facing shipping companies in the competitive liner market. For a shipping company, failure to add sufficient capacity in a booming market can not only result in the loss of sales and market share, but also endanger its long-term competitive position. However, over-investment is also harmful to the business, because too many empty slots in a voyage can result in too low a profit to cover the high financial costs. This decision process can be further complicated by the uncertainties in future demand and the strategic behaviors of competitors. Due to the cyclic nature of the shipping market and the newbuilding lag (Luo et al., 2009), the individual optimal decisions based on the expectation of future demand can collectively create excessive capacity in the industry, which can accelerate the decrease of the freight rate. For example, before the global financial crisis, the fast growth in shipping demand motivated shipping companies to expand capacity. According to the news from Bloomberg (Wienberg & McLaughlin, 2009), Drewry has predicted that the global container market capacity will grow 8% in 2009 and 10% in 2010, even though the demand for shipping has decreased significantly due to the crisis. The total industrial loss amounted to $20 billion, compared with a $5 billion profit in 2008. According to an executive officer of Maersk Line, "If you start going for market share in a declining market, it will only create an even stronger downward spiral, at this level, we all lose substantially'. This exemplifies the importance of capacity investment to the container shipping market and private business operation.

* *Corresponding Author*: Tel.: (852) 2766 7414; Fax: (852) 2330 2704; Email: lgtmluo@polyu.edu.hk.

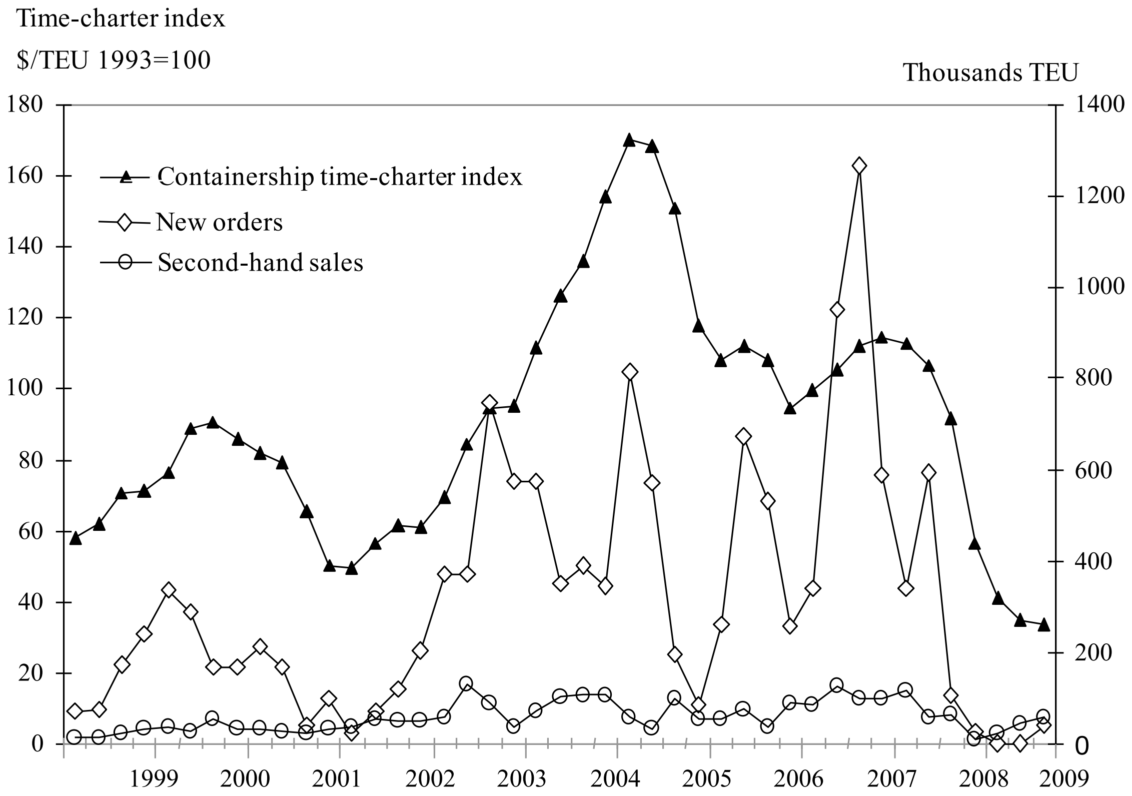

Figure 1: Container time charter index and orders
Source: Clarkson Research Services Limited 2009

Figure 1 displays the container ship time-charter rate and world total container capacity orders (in thousand TEU slots) from 1999 to 2009. When the freight rate (as represented by the time-charter index) is increasing, the expected high profitability in container shipping services motivates ship owners to order new vessels so as to attract customers with better services and gain a larger share in the global competitive market. When the capacity increase cannot keep pace with the demand, the market freight rate will fluctuate, which will exert negative impacts not only on shipping companies, but also on international trade, maritime safety and the environment (Luo et al., 2009). As industrial capacity is determined collectively by the investment behavior of individual shipping companies (Stopford, 2009), analyzing individual behavior in capacity investment in the liner shipping industry is essential to understanding economic factors that drive the industrial capacity change, and ultimately the fluctuation in the container freight rate.

According to Lloyd's Fairplay ship registration database, there are 926 containership owners on January 1, 2009. The biggest owner is Moller-Maersk A/S who owns 4.65% of the market capacity, followed by Offen C-P, COSCO, and CMA CGM Holding. These four biggest container companies, sharing 14.82% of the world container capacity, were active in investing vessels from 1999 to 2008. Their investment accounted for 15.68% of the total investment in the industry. This reveals the important contribution of the larger liner shipping companies to the world capacity growth. On the other hand, this database also reveals that around 85% of the world fleets are still controlled by many smaller shipping companies. To mitigate the influence of market competition, many shipping companies pooled their vessels together to form global alliances. The existence of alliances may to some extent influence the operation of individual firms. However, members in the alliance still need to make investment decisions by themselves. Therefore, we do not take the influence of the alliance into consideration in our capacity investment analysis.

Generally, there are two main types of capacity investment: non-strategic and strategic. The former invests to replace old ships, meet the increasing demand, or buffer possible demand shocks (Driver, 2000; Lieberman, 1987; Kamien & Schwartz, 1972). When the ship is getting bigger and future demand is uncertain, non-strategic investment can often lead to excessive capacity in shipping (Fusillo, 2003; Le & Jones, 2005). The latter invests to improve market positions in the competitive environment (Hay & Liu, 1998; Spance, 1979).

The purpose is to preclude the capacity expansion of competitors (Gilbert & Lieberman, 1987; Lieberman, 1987; Porter & Spence, 1982; Reynolds, 1986) and deter potential new entrants. Many game theory studies found that incumbents often use excessive capacity to threaten new entrants and prevent market entry (Dixit 1979; Dixit 1980; Haruna 1996; Lyons 1986; Spence 1977; Wenders 1971).

Despite the significant role of capacity investment in liner shipping, studies on modeling shipowners' investment behavior are limited. Among them, Fusillo (2003) used entry-deterrence to model excess capacity and tested the existence of excessive capacity using observed data. His empirical results show that the top four carriers added excessive capacity when there are entry threats. Wu (2009) formulated optimal fleet capacity for a shipping company assuming cost minimization, and computed optimal capacity for three carriers from 1992-2006. His findings suggest that the strategy of holding excess capacity and maintain market power may have implicitly played a crucial role in determining fleet capacity. Bendall and Stent (2005) assessed ship investment under uncertainty, using ROA (Real Option Analysis), in an express liner service. However, there is no existing research on modeling shipowners' investment behavior and analyzing the underlining factors for ship investment.

The importance of the capacity investment in the liner shipping industry and the lack of corresponding analyses inspired us to study the underlying key factors in capacity investment decision-making using the observed ship investment data. The motivations for capacity investment include not only the operational needs to meet market demand, but also strategic measures to keep the market position in a competitive environment. Different responses of the capacity investment to the market condition and competitors' strategy were tested for the shipping companies with different sizes. The results of this study not only extends the current understanding about capacity investment behavior in the container shipping market and provide empirical test about the existence of strategic investment behavior, but also highlights the underlining forces for the fluctuation of the container freight market. The results can also benefit both private business operation in shipping, ship operation, ship financing and ship trading, and for the public policies in national and international agencies for maritime transportation.

This paper starts with a theoretical analysis of the container ship investment behavior. It first investigates the factors influencing capacity investment without competition among firms. Then it analyzes the effects of competition among firms in investing behavior by a theoretical model assuming optimal utilization rate in the short run. The data used for this analysis, and the description of the variables are then presented, followed by the presentation of the empirical results and explanations. A summary of this study is presented in the last section.

2. A theoretical analysis on the capacity investment behavior of shipping companies

As stated in the introduction, shipping companies expand their capacity to meet the expected market demand and to improve their respective market condition. We define the capacity investment in both situations as the orders for new ships as well as the acquisition for second-hand ones. It is recognized that shipping companies can expand their capacity through chartering. However, short-term chartering is not a popular practice in container shipping (Gorton et al., 2009). Large shipping companies, such as Maersk, own all the ships in their operation. Smaller shipping companies may charter a ship to supplement short-term capacity shortage. Nevertheless, this cannot be a long-term solution as it decreases the charterer's market competitiveness by paying high short-term charter rate. In addition, this practice does not change the financial responsibility of the owner. Therefore, it can be treated as an irrelevant intermediate alternative, as the owner is facing the same market in their capacity investment decision. For the bareboat charter, normally it is the charterer who initiates the new order and will take control when the ship is delivered. This data is already included in the new order. Therefore, to study the capacity investment behavior in container shipping, we can safely neglect the ship chartering activity.

2.1. Non-strategic capacity investment

The fundamental reason for a shipping company to increase its capacity is to meet the market demand. When the demand is high and all the available ships are in service, the shipping company is better to purchase a ship if it is not economical to run the ship faster. To illustrate the decision factors under this situation, we analyze the investment behavior of one company running a fixed service between two ports.

Assume the shipping company has N identical container vessels of K TEU slots, and uses n vessels in transportation. For each vessel, the operation cost is C and the lay-up cost is LC. The distance between two ports is L. The voyage cost $V(s)$ is a function of ship speed s. Using ρ for the average working hours of one ship in a year, $s\rho/L$ is the total number of trips that a ship can sail in a year if it runs at speed s. For simplicity, assume capital and financial cost is part of the operating cost C. The shipping company is facing demand Q and the market freight rate is P.

Under these conditions, the shipping company's problem is to maximize its annual profit with respect to number of ships (n) it used and ship speed s.

$$\max_{n,s} \pi = \max_{n,s} \left[PQ - nC - n\frac{s\rho}{L}V(s) - (N-n)LC \right] \tag{1}$$

s.t. $n\frac{s\rho}{L}K \le Q$ and $n \le N$.

Solving this problem using the Kuhn-Tucker method, we can get $P = \frac{V(s) + sV'(s)}{K}$, which determines the optimal speed based on the freight rate and vessel condition; and $n\frac{s\rho}{L}K = Q$, which indicates that the shipping company will meet all its demand. Depending on whether there are layups, there are two possible results:

Case 1: $n<N$. In this case, $LC + sV'(s)\frac{s\rho}{L} - C = 0$, which describes the optimal vessel speed when there are layups in the company. Because the shipping company will not increase its capacity when there are lay-ups, no further discussion is necessary in this case.

Case 2: $n=N$. In this case, the speed is determined by $s^* = Q\frac{L}{N\rho K}$. In other words, the shipping company has to increase the speed of its ships to accommodate the increasing demand. However, technology limitations and the faster increasing rate in voyage cost make this option unsustainable. In this case, it is better for the shipping company to purchase additional ships, as long as the savings from the reduced speed can offset the incremental capital and financial cost, operation cost and voyage cost. Assume that the shipping company is a price taker and the quantity demanded is fixed, the problem is to determine the optimal number of vessels to purchase to minimize the total operation cost:

$$\min_I C(I) = (N+I)\left[C + \frac{s\rho}{L}V(s) \right] \tag{2}$$

where the speed is constrained by $s = \frac{QL}{(N+I)\rho K}$. The first order condition for this problem is:

$$C + \frac{s\rho}{L}V(s) + (N+I)\frac{\rho}{L}\left[V(s) + sV'(s)\right]\frac{ds}{dI} = 0 \tag{3}$$

Differentiating the shipping speed constraint *w.r.t.* the new investment I, it is clear that:

$$\frac{ds}{dI} = -\frac{QL}{(N+I)^2 \rho K} \tag{4}$$

Substitute ds/dI in equation 3 with the expression in equation 4, and eliminating Q using the speed constraint, the first order condition can be simplified to:

$$C = sV'(s)\frac{s\rho}{L} \qquad (5)$$

Equation 5 is the optimality condition of adding one more ship. The left-hand side is the additional capital, financial and operational cost, which are the fixed cost in a year with one more ship. The right-hand side is the annual incremental cost savings from the reduced speed with one more vessel. This condition determines the optimal speed of the vessels. From this optimal speed, assume equal revenue allocation to each vessel, then the optimal number of vessels the company needs to purchase is:

$$I = \frac{PQ}{C + \frac{s\rho}{L}V(s)} - N \qquad (6)$$

Eq. (6) states that for non-strategic investment, the shipowners' capacity will increase with market demand (price, quantity demanded, and average haul length), and decrease with the capital and financial cost, operation cost, and voyage cost. The average size of the vessels also plays an indirect role in investment decision making, as shown from the speed constraint. As speed is relatively fixed, the larger the ship size, the fewer number of ships will be invested.

Finally, without considering the competitive behavior, the capacity investment in the container shipping market can be written as:

$$I = F(\overset{+}{Q}, \overset{-}{N}, \overset{-}{K}, \overset{+}{Tc}, \overset{+}{GTc}), \qquad (7)$$

where the sign (+/-) on top of each parameter indicates the positive/negative relationship between the capacity investment and that parameter. *Tc* is the time-charter rate. It is used to represent the container freight rate for two reasons. First, these two variables are highly correlated: an increase in freight rate will bring up the charter rate, while a decrease in freight rate will push down the charter rate. The correlation coefficient between these two variables from 1993 to 2006 is 0.83 (Figure 2). Secondly, we need monthly data for statistical analysis. Monthly data is available for the time-charter rate, but not the freight rate. *GTc* is the growth rate of time-charter rate.

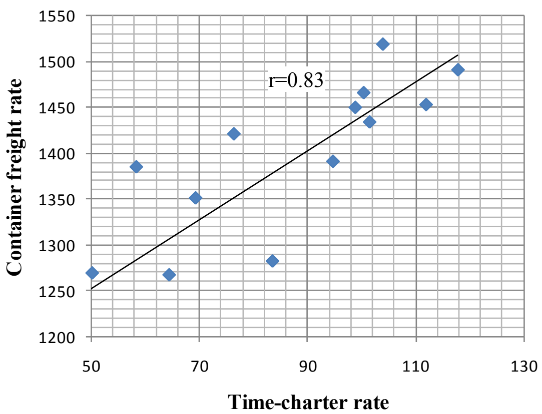

Figure 2: Correlation between container freight rate and time-charter rate between 1993 and 1996

2.2. Strategic capacity investment

In this section, we discuss capacity investment when there is market competition. As stated in the introduction, there are two types of strategic capacity investment. One is the competition among firms vying for market share, and the other is to preempt the market using excessive capacity. Because the latter type was studied in (Fusillo, 2003), this section concentrates on the first type.

There are many different assumptions on the structure of the liner shipping market (Shashikumar, 1995), and there is no commonly agreeable model that can be used to describe the market structure in practice. However, to identify important factors in the capacity investment decision under a competitive environment, it is sufficient to begin with a simple duopoly model and examine how one company's capacity decision affects its competitors.

2.2.1. Model assumptions

To simplify the analysis, we consider a market with two shipping companies, denoted with subscripts i (i=1, 2). We use k_i to denote their current capacity, q_i for their throughputs, and Q for the total throughput ($Q= q_1 + q_2$). To further simplify the process, similar to (Driver, 2000), we use variable u_i to represent the capacity utilization rate of the firm i. Then the throughput and capacity relationship of that firm can be written as $q_i = k_i u_i$.

We formulate the competition model in Cournot-fashion in which shipping companies compete with each other using the quantity of output (by capacity and slot utilization), in a market with a linear demand function $p = a - b(q_1 + q_2)$, where p is the market price, a and b are positive parameters representing base demand and demand sensitivity respectively.

On the cost side, following section 2.1, we assume that the cost function has two parts. The first part has constant marginal/average cost in the throughput, representing a fixed cost. The second part is the voyage cost that varies with utilization rate and output. As the fuel consumption increases faster than the speed increase at an exponential rate (Beenstock & Vergottis, 1989; Stopford, 2009), we assume the voyage cost function for company i is $V(q_i, u_i)=ru_i^2k_i$, where r is an adjust parameter in the voyage cost. Then the total cost $C_i=cq_i + V(q_i, u_i) = cu_ik_i + ru_i^2k_i$, where c is the average/marginal cost.

2.2.2. Quantity competition in the short run

When the carrying capacity is fixed, the quantity competition between shipping companies is to rationalize capacity utilization, i.e., each shipping company maximizes its profit by adjusting its u_i:

$$\max_{u_i} \pi_i = pq_i - C_i = [a - b(u_1k_1 + u_2k_2)]u_ik_i - cu_ik_i - ru_i^2k_i, \quad i = 1,2 \quad . \tag{8}$$

Since $\partial^2\pi_i / \partial u_i^2 = -2rk_i - 2bk_i^2 < 0$, the profit function of each firm is concave in its own utilization rate, then the utilization rate satisfying the first order condition

$$\partial\pi_i / \partial u_i = k_i[a - b(u_1k_1 - u_2k_2)] - bu_ik_i^2 - ck_i - 2ru_ik_i \equiv 0 \tag{9}$$

maximizes its profit. Solving the first order condition (Equation 9), the equilibrium utilization (u_1^*, u_2^*) can be obtained:

$$u_1^* = \frac{(a-c)(2r + bk_2)}{4r^2 + 4brK + 3b^2k_1k_2}, \tag{10}$$

$$u_2^* = \frac{(a-c)(2r + bk_1)}{4r^2 + 4brK + 3b^2k_1k_2}, \tag{11}$$

where $K = k_1 + k_2$. From Equation 10 and 11, it is clear that the capacity of a shipping company will not only affect the equilibrium utilization rate of its own, but also the competitors'. Using this as an intermediate result and understanding that there are limitations using this method to meet increasing demand, we consider next the implication on capacity investment decision under a competitive environment.

2.2.3. Capacity investment in the long run

In the long run, capacity can increase with continued investment when a shipping company expects future demand increase, and/or to compete with others for more cargoes. We distinguish the investment in capacity (I_{it}) with the existing capacity (k_{it}). For simplicity, we assume that the ships will be delivered in one year, i.e., $k_{it+1}=k_{it}+I_{it}$, and shipping companies will adjust the optimal utilization according to Equation 10 and 11 using the new capacity. In addition, the market price will also change corresponding to the market demand in *t+1*.

The net profit function after firm *i* gets the ships ordered can be written as

$$N\pi_{it+1} = [p_{t+1}(u^*_{it+1}, k_{it+1}) - c]q_{it+1} - V(q_{it+1}, u^*_{it+1}) - p^I dk_{it+1}, \text{ i=1, 2}$$

where $q_{it+1}=u^*_{it+1}k_{it+1}$; p^I is the unit price of the capacity, *d* the annualized capital cost rate. Actually, the last term is the capital cost of the cumulative capacity. Note that the price (p_{t+1}), outputs (q_{it+1}), utilizations (u_{it+1}) are all a function of the investment decision I_{it}. Therefore, the current investment (I_{it}) will determine, ceteris paribus, the profit in the next period. Hence, the optimal capacity investment can be determined by the first order condition for maximizing the profit of the subsequent period *w.r.t.* I_{it}:

$$\frac{\partial N\pi_{it+1}}{\partial I_{it}} = \frac{\partial N\pi_{it+1}}{\partial u^*_{it+1}}\frac{\partial u^*_{it+1}}{\partial I_{it}} + \frac{\partial N\pi_{it+1}}{\partial I_{it}} \equiv 0 \quad . \tag{12}$$

The second order condition, $\partial^2 N\pi_{it+1}/\partial I_{it}^2<0$ (refer to Equation 17), ensures profit maximization when I_{it} satisfies Equation 12. Using implicit function theorem and comparative statics, it is possible to determine how I_{it} changes with various variables in the model. The comparative static analysis is provided in Appendix A. The results are expressed in the next equation:

$$I_{1t} = F(\overset{+}{a_t}, \overset{-}{b_t}, \overset{-}{c}, r, \overset{-}{d}, \overset{-}{p^I}, \overset{-}{k_{1t}}, \overset{-}{k_{2t}}, \overset{-}{I_{2t}}) \; . \tag{13}$$

Some of the results from the comparative static analysis, such as the the influence of the market demand, operational cost, and investment cost, are straight forward and consistent with the results in section 2.1. In addition, Equation 13 also includes the effects of competition: capacity investment in one company decreases with its own capacity, competitors' capacity, and competitors' capacity investment. Furthermore, the level of impacts on the investment also varies with different firm capacity, which will be tested in the empirical analysis.

Combing the results from sections 2.1 and 2.2, the final function that illustrates the decision factors for capacity investment of firm 1 can be written as:

$$I_{1t} = F(\overset{+}{Q}, \overset{-}{K}, \overset{+}{Tc}, \overset{+}{GTc}, \overset{-}{b_t}, \overset{-}{c}, r, \overset{-}{d}, \overset{-}{p^I}, \overset{-}{k_{1t}}, \overset{-}{k_{2t}}, \overset{-}{I_{2t}}) \; . \tag{14}$$

This theoretical result provides a starting point for an econometric analysis for the important factors in shipping companies' capacity investment behavior. Next, we explain the data used in the empirical analysis.

3. Data

Lloyd's Fairplay provided a database of detailed information on vessels, owners, orders, deliveries, and transaction information for over 120 thousand vessels over 100 GT. Among them, there were 5,724 container vessels owned by 926 shipowners as of January 1, 2009. For the purpose of this paper - to analyze the investment behavior of existing companies, new firms' investment record during this period were excluded. In other words, only the firms who have had capacity since 1999, or those who did not invest for the first time during 1999 and 2008 were included. In this analysis, a total of 767 companies were selected, which involved 4,591 observations, 4913 vessels, 60% (9.7 million TEU) newbuildings and 40% (6.5 million TEU) second-hand vessels. If an existing firm did not invest in a year, its total investment is 0; otherwise, it is the total number of TEU slots invested in this year. All the variables used in the estimation are listed in Table 1.

Table 1: Descriptive statistics

Variables	Unit	Observations	Mean	Std. Dev.
INV_{it}	000 TEU	4995	2.94	15.4
K_{it}	000 TEU	4995	20.5	60.45
$INVAVG_{it}$	000 TEU	4995	0.57	1.57
Q_t	000000 TEU	4995	379	112
$GROWQ_t$	%	4995	11.04	2.53
$SHARE_{it}$	%	4995	0.2	0.59
$CHSHARE_{it}$	%	4591	-0.28	31.23
OEX_{it}	%	4966	7.77	6.26
$OINV_{it}$	%	4966	16.22	11.19
TC_{it}[a]		4966	98.13	28.16
GTC_{it}[b]	%	4966	3.48	24.97
NBP_{it}[c]		4945	103.1	32.61
SEP_{it}[d]		4966	100.2	19.59

Note: a, b, c, and d are all form Clarkson Research Services Limited 2009
[a] Containership Time charter Rate Index: based on $/TEU for 1993 = 100.
[c] Containership New-building Prices Index: based on average $/TEU for Jan 1988 = 100.
[d] Containership Second-hand Prices Index: based on average $/TEU for Jan 1988 = 100.

The dependent variable, INV_{it}, is the new investment of container vessels including orders for new ships and second-hand ships for firm *i* in year *t*. Because of the new building lag, INV_{it} is not k_t-k_{t-1}. However, since we focus on explaining the investment decisions, we will not distinguish newbuildings and second-hand vessels, as they all express shipping companies' intention to increase their capacity.

K_{it}: the total capacity (Thousand TEU) of firm *i* at January 1 of year *t*. In the Lloyd's Fairplay database, we can only calculate the capacity level of each shipowner on January 1, 2009. However, the database provides detailed information for each vessel, including the order year, delivery year, and the acquired year if it is a second-hand ship. Unfortunately, it does not keep information about the scrapped ships.

Information about ship demolitions from 2004 to 2008 was obtained from the CSIN (Clarkson's Shipping Intelligence Network). Combining such information, we can calculate the capacity level of each company from 1999 to 2008 using the equation $k_{it-1}=k_{it}-ADDITIONS_{it}+SELLS_{it}+SCRAP_{it}$, where $ADDITIONS_{it}$ includes the delivery of newbuildings and second-hand ships, $SELLS_{it}$ is firm *i*'s selling of second-hand ships. We ignore ship demolitions before 2004 because of data unavailability. This will not influence the analysis as the market total demolition only accounted for 0.5% of the total capacity (TEU) from 1999 to 2008.

$SHARE_{it}$: firm *i*'s share of total industry capacity in year *t*, defined as $SHARE_{it}=K_{it}/\Sigma_i K_{it}$.
$CHSHARE_{it}$: the change of share for firm *i* from year *t*-1 to year *t,* which is defined as $CHSHARE_{it}=SHARE_{it}/SHARE_{it-1}$ -1. This value changes with both its own capacity and its competitors' capacity.

Q_t: industry demand which is the total container throughput in year *t*. Because there is no route specific demand information and ship deployment information for each individual shipping route, we assume that all the firms face the same global industry demand.

$GROWQ_t$: the demand growth rate, defined by $GROWQ_t=Q_t/Q_{t-1}$-1. This variable is included to test the impacts of the market trends, instead of the market status, on the investment behavior. It represents the non-strategic investment behavior in the container shipping companies as introduced in section 2.

TC_{it}: the container ship time-charter index. If a firm invested ships in year *t*, TC_{it} is the monthly average time-charter index in the months the ships are ordered. If not, it is just the time-charter index of that year.

GTC_{it}, NBP_{it} and SEP_{it} are calculated in the same way, but they represent the growth rate of time-charter index, newbuilding price index, and second-hand ship price index. The data for these three variables were obtained from Clarkson's Shipping Intelligence Network (CSIN).

INR_t: a dummy variable represents the market status. It is 1 if the time-charter rate is increased in year *t*, and 0 otherwise.

OEX_{it}: the capacity expansion of the competitors for firm *i*, defined as $OEX_{it}=\Sigma_{j\neq i}(K_{jt}-K_{jt-1})/\Sigma_{j\neq i}K_{jt-1}$. It is the increasing rate of all other firms' capacity except firm *i*, which is designed to test the competition among firms. Comparing with the variable $CHSHARE_{it}$ which takes into account its own and competitors' expansion, OEX_{it} captures only the influence of all the competitors' capacity expansion. The correlation between these two variables is -0.03, indicating that they are not perfectly correlated.

$OINV_{it}$: competitors' investment rate in year *t*, defined as $OINV_{it}=\Sigma_{j\neq i}INV_{jt}/\Sigma_{j\neq i}K_{jt}$. It represents the ratio of aggregated investment with aggregated capacity of all other firms. Unlike OEX_{it} which is the actual capacity expansion rate of the competitors, $OINV_{it}$ is the rate of investment of the competitors, which could lead to the increase of competitors' capacity in the next time period. This variable is designed to capture firms' responses to the investment activities of the competitors.

$INVAVG_{it}$ is a variable representing the average investment size of firm *i* in year *t*. It is used to capture the impact of ship size on the capacity investment behavior of the investor.

Finally, companies with different sizes may respond to the capacity investment of the competitors differently. To detect this behavior, we created interaction terms using the capacity share of each firm ($SHARE_{it}$) and some other independent variables, including $CHSHARE_{it}$, $GROWQ_t$, OEX_{it}, and $OINV_{it}$.

4. Estimation and results

Table 2 summarizes the result of three different models for the capacity investment behavior. Model (1) included all of the independent variables and omitted interaction terms. Because NBP_{it} and SEP_{it} are highly correlated, only NBP_{it} was included in the mode. Model (2) included the interactions using the $SHARE_{it}$ variable. Since market trends may influence shipowners' investment behaviors, in model (3), we added the interaction of the dummy variable for increasing market, INR_t, with OEX_{it} and $OINV_{it}$.

Table 2 Regression results for three capacity investment models.

	Dependent variable: INV_{it}					
	Model (1)		Model (2)		Model (3)	
Independent variables	Coefficient	Prob.	Coefficient	Prob.	Coefficient	Prob.
C	3.8752	0.0502	0.6226	0.3178	-10.3268	0.0001**
$INVAVG_{it}$	4.2274	0000**	3.1230	0000**	3.1290	0000**
$SHARE_{it}$	8.2651	0000**	15.7629	0000**	12.3311	0000**
$CHSHARE_{it}$	-0.0071	0.1812	-0.0049	0.7252	-0.0026	0.6210
$SHARE_{it}$ × $CHSHARE_{it}$			-0.0389	0.0033**	-0.0752	0.0043**
Q_t	-0.0233	0.0063**	-0.0023	0.2272	0.0465	0.0001**
$SHARE_{it}$ × Q_t			-0.0916	0000**	-0.0741	0000**
$GROWQ_t$	-0.1304	0.2982	0.0102	0.9529	0.2052	0.0460*
$SHARE_{it}$ × $GROWQ_t$			-0.0110	0.6064	0.0494	0.6392
OEX_{it}	0.5984	0.0001**	0.0603	0.1787	-0.5516	0.0068*
$SHARE_{it}$ × OEX_{it}			2.2354	0000**	2.0940	0000**
OEX_{it}×INR_t					2.1411	0000**
$OINV_{it}$	0.0788	0.0715	-0.0395	0.1708	-0.2577	0000**
$SHARE_{it}$ × $OINV_{it}$			0.6946	0000**	0.7071	0000**
$OINV_{it}$ × INR_t					-0.7436	0000**

TC_{it}	0.0077	0.2289	0.0068	0.2552	0.0175	0.2695
GTC_{it}	3.2909	0.0042**	0.3076	0.6955	1.9948	0.1217
NBP_{it}	-0.0213	0.2069	-0.0124	0.4002	-0.0380	0.0698
Observation	4591		4591		4591	
R-squared	0.409		0.594		0.598	
Adjusted R-squared	0.407		0.593		0.596	
Durbin-Watson	1.770		2.253		2.253	
Log likelihood	-18049		-17187		-17165	
F-statistic	316		446		400	

* Significant at the 0.05 level, two-tailed test.

** Significant at the 0.01 level, two-tailed test.

The significance of including the interaction terms in models 2 and 3 was tested respectively using the likelihood ratio test. The test statistics between model 2 and model 1 was -2[-18,049 - (-17,187)] = 1,725, while that between model 3 and model 1 was -2[-18,049 - (-17,165)] = 1,770. The 1% critical value from the chi-squared distribution with 2 degrees of freedom was 9.21. Hence, the hypothesis that there is no difference with or without the interaction terms was rejected. Models (2) and (3) with interaction terms are appropriate. Since model (3) includes the most interaction terms, it is the basis for the following discussion.

Judging from the results in Table 2, the signs on the estimated coefficients for most of the variables conform to the theoretical model, especially in the full models of (2) and (3). The coefficient of $INVAVG_{it}$ was positive and significant at the 1% level in all of the three models. This result is consistent with previous research that the lumpiness in ship investment may cause excessive capacity in the shipping industry (Fusillo, 2003; Le & Jones, 2005). The coefficient of $SHARE_{it}$ was positive and significant in all of the three models. This is reasonable because larger firms could earn more to support capacity investment. This result is also consistent with (Fusillo, 2003), who found that large firms in the shipping industry, especially the top four companies, are using preemptive capacity to deter the new entrants, which may require the larger firms to invest more.

Comparing models (1) to (2) and (3), it can be seen that larger firms tend to respond to the market share change differently in the investment decision-making. The coefficient on $CHSHARE_{it}$ was not significant in all the three models, indicating that this variable is not an important factor in investment decision making. However, in models (2) and (3), all the interactions between $SHARE_{it}$ and $CHSHARE_{it}$ were negative and significant. Because the dependent variable is the quantity of investment and $CHSHARE_{it}$ is the current share change, the result suggests that large shipping companies are trying to compensate their past market share changes. If they find their share reducing, they will try to invest more; if they have already experienced an increasing market share, they will be more conservative in investment.

The coefficient estimates on Q_t and $SHARE_{it} \times Q_t$ were both significant, but their signs were different, positive for the first and negative for the second. This shows that while high market demand can motivate capacity investment, smaller firms are more responsive than larger ones. Whenever there is a demand increase, smaller firms will first feel the capacity shortage, and also the needs to acquire more vessels. In contrast, larger firms have more available capacity to buffer demand increase. Therefore, they are comparatively less responsive to the demand increase in the ship purchasing decision. The positive and significant coefficient on demand growth rate ($GROWQ_{it}$) suggests that high demand increasing rate will motivate capacity investment. The non-significant coefficient on ($SHARE_{it} \times GROWQ_{it}$) suggests no obvious difference in capacity investment between large and small firms facing a growing demand.

The coefficients on OEX_{it}, $OEX_{it} \times INR_t$ and $SHARE_{it} \times OEX_{it}$ were all significant, indicating strategic capacity investment in a competitive environment. From the first two variables, it is clear that although a firm's capacity investment will decrease with competitors' capacity expansion, when the market is increasing, its investment will increase with competitors' investment. The result of the last variable indicates that the investment of a larger company increases with competitors' expansion. This explains the shipping companies' strategy in maintaining their market share.

The coefficients on $OINV_{it}$, $OINV_{it} \times INR_t$, $SHARE_{it} \times OINV_{it}$ were also significant, indicating the importance of the competitors' investment rate on capacity investment of a shipping company. The negative coefficients on the first two variables indicate that shipping companies are trying to avoid investing at the same time with the competitors, especially when the freight rate is increasing. This result implies that there may be some rationality in capacity investment in the container shipping industry. The positive coefficient on $SHARE_{it} \times OINV_{it}$ indicates that larger companies are less influenced by the negative impact of competitors' capacity investment decisions.

The above analyses confirm the mass psychology of capacity investment in shipping (Stopford, 2009) when the demand is increasing. In addition, our study also reveals obvious strategic behavior in capacity investment. Furthermore, there are distinct differences between the market players with different sizes, and there are different responses to the observed capacity change of the competitors, and their investment level. The finding indicates that strategic investment reduces the immediate capacity expansion in competing firms. It could reduce over investment in shipping capacity and promote market efficiency by avoiding industry oversupply. However, this efficiency improvement diminishes with firms' long-term strategy in keeping market shares, especially the larger firms'.

Finally, three variables, TC_{it}, GTC_{it}, and NBP_{it}, were not significant. TC_{it} and GTC_{it} were not significant, possibly because they are not as direct a factor in firm's capacity investment as market demand: firms based on the market demand for their capacity investment strategy, not the market price. NBP_{it} was not significant, which may be because new building market is a derived market: firms order more ships not because the price is low, but because the demand for transportation services is high. Therefore, the newbuilding price is not a significant factor in capacity investment.

5. Summary and Conclusion

This study indentified and tested some major factors determining capacity investment behavior in the container shipping industry, using both theoretical and empirical analyses. The theoretical part analyzed the capacity investment behavior from two different aspects: operational considerations for cost minimization and strategic behavior in market competition. For the operational requirement, the decision for investing another ship is made through comparing the gain from reducing ship speed and the additional operating and capital costs. For the strategic behavior, we adopted a Cournot-like model where shipping companies compete by utilization-rate in short term, and in long term using capacity investment. The empirical analysis used actual existing shipping company investment data, which included 767 containership owners over the period 1999-2008, with a total of 4,591 observations.

Results from the empirical analysis suggest that when existing companies make capacity investment decisions, they consider both the operational needs to supply the demand growth, and the strategies for market competition. The positive and significant impacts on capacity investment from market demand and its growth rate reveals the investment behavior in meeting the operation requirements. Furthermore, firms with different sizes have different responses to demand, although they are both inclined to invest more when demand is increasing. Small companies tend to be more responsive to demand change than the larger ones, as they have less existing capacity to accommodate the high demand.

A firm's investment behavior facing market competition includes the responses to its market share, change of market share, competitors' capacity expansion, and investment. Market share has a positive and significant impact on capacity investment. The change of market is not a significant factor for smaller firms' investment decisions, because their market share is very small anyway. However, large firms always try to compensate their past market share changes: If they find their market share decreasing, they will invest more.

The response to other firms' capacity expansion reveals shipping companies' competitive capacity investment behavior with respect to the actual capacity change of the competitors in the previous year. Generally, a firm's capacity investment decreases with the capacity expansion of competitors. However, larger firms will increase their capacity investment to keep their market share. In addition, in a booming market, a company will invest more even the competitors’ capacity is expanding. This could be a major factor for overcapacity in container shipping.

The response to other firms’ capacity investment, which is different from the response to the competitors’ capacity expansion, reveals the competitive investment behavior with respect to others’ investment. A company will refrain from investing more while others make aggressive investment plans, especially when the market freight rate is increasing. However, for larger companies, the aggressive investment of others will increase their investment, in order to avoid the loss of market share.

Finally, this paper provides insights into capacity investment behavior for shipping companies with different sizes and market share under different market situations, which could benefit not only private sectors associated with the shipping industry, but also the public policy-makers in national and international maritime agencies. Understanding the current practice in shipping capacity investment can help the shipping companies, shipowners and ship-operators to find the best opportunity to expand their capacity, so as to secure their market position. For the institutions providing ship financing and organizations in ship trading, this could help them understand the individual investment behavior in shipping capacity, so as to provide better service to their customers and reduce the risk in ship financing. In the public sector, knowing the capacity investment behavior could help the national and international agencies to advise appropriate maritime policies to regulate the capacity investment activities so as to mitigate the impact of alternative over-capacity and supply shortage in the container shipping industry.

Acknowledgement

This research has been supported by Hong Kong Research Grants Council through grant PolyU52380/07E, and The Hong Kong Polytechnic University internal grant G-U815.

References

Beenstock, M. & Vergottis, A., 1989. An econometric model of the world market for dry cargo freight and shipping. Applied Economics, 21, pp.339-56.

Bendall, H.B. & Stent, A.F., 2005. Ship investment under uncertainty: valuing a real option on the maximum of several strategies. Maritime Economics and Logistics, 7, pp.19-35.

Dixit, A., 1979. A model of duopoly suggesting a theory of entry barriers. The Bell Journal of Economics, 10(1), pp.20-32.

Dixit, A., 1980. The role of investment in entry-deterrence. The Economic Journal, 90, pp.95-106.

Driver, C., 2000. Capacity utilisation and excess capacity: theory, evidence, and policy. Review of Industrial Organization, 16, pp.69-87.

Fusillo, M., 2003. Excess capacity and entry deterrence: the case of ocean liner shipping markets. Maritime Economics and Logistics , 5 , pp.100-15.

Gilbert, R.J. & Lieberman, M., 1987. Investment and coordination in oligopolistic industries. Rand Journal of Economics, 18(1), pp.17-33.

Gorton, L., Hillenius, P., Ihre, R. & Sandevarn, A., 2009. Shipbroking and Chartering Practice. 7th ed. London: Informa.

Haruna, S., 1996. A note on holding excess capacity to deter entry in a labour-managed industry. Canadian Journal of Economics , 29 , p.493–499.

Hay, D.A. & Liu, G.S., 1998. The investment behaviour of firms in an oligopolistic setting. The Journal of Industrial Economics, 46, pp.79-99.

Kamien, M.I. & Schwartz, N.L., 1972. Uncertain entry and excess capacity. The American economic review, 62(5), pp.918-27.

Le, D.T. & Jones, J.B., 2005. Optimal investment with lumpy costs. Journal of Economic Dynamics and Control, 29, pp.1211-36.

Lieberman, M.B., 1987. Excess capacity as a barrier to entry: An empirical appraisal. The Journal of Industrial Economics , 35 , pp.607-27.

Luo, M., Fan, L. & Liu, L., 2009. An econometric analysis for container shipping market. Maritime Policy and Management, 36(6), pp.507-23.

Lyons, B.R., 1986. The welfare loss due to strategic investment in excess capacity. International Journal of Industrial Organization , 4 , pp.109-19.

Porter, M.E. & Spence, M., 1982. The capacity expansion process in a growing oligopoly: the case of corn wet milling. National Bureau of Economic Research:University of Chicago Press.

Reynolds, S.S., 1986. Strategic capital investment in the american aluminum industry. Journal of Industrial Economics , 34 , pp.225-45.

Shashikumar, N., 1995. Competition and models of market structure in liner shipping. Transport Reviews, 15(1), pp.3-26.

Spance, M.A., 1979. Investment strategy and growth in a new market. The Bell Journal of Economics, 10(1), pp.1-19.

Spence, M.A., 1977. Entry, Capacity, Investment and Oligopolistic Pricing. The Bell Journal of Economics, 8(2), pp.534-44.

Stopford, M., 2009. Maritime Economics. Routledge.

Wenders, J.T., 1971. Excess Capacity as a Barrier to Entry. Journal of Industrial Economics, 20(1), pp.14-19.

Wienberg, C. & McLaughlin, K., 2009. Maersk Says Container Market to Shrink More Than 10% (Update2). [Online] Available at: http://www.bloomberg.com/apps/news?pid=20601087&sid=aV6ml
lBFw [Accessed 6 July 2010].

Wu, W.M., 2009. An approach foe measuring the optimal fleet capacity: evidence from the container shipping lines in Taiwan. International Journal of Production Economics, 122(1), pp.118-26.

Appendix A

The comparative static analysis of the investment equation of section 2.2.3 are developed in detail here. Substitute all the variables into the net profit equation and simplify it, we get

$$N\pi_1 = \frac{(a-c)^2(2r+bI_2+bk_2)^2(I_1+k_1)(r+bI_1+bk_1)}{M^2} - p^I d(k_1+I_1) \tag{15}$$

Where $M = 4r^2 + 4brk_2 + bI_1(4r+3bk_2) + 4brk_1 + 3b^2k_2k_1 + bI_2(4r+3bI_1+3bk_1)$.

The first order condition in equation 12 is

$$F = \frac{\partial N\pi_1}{\partial I_1} = \frac{\left\{\begin{matrix}(a-c)^2 r(2r+bI_2+bk_2)^2[4r^2+4brk_2+bI_1(4r \\ +5bk_2)+4brk_1+5b^2k_2k_1+bI_2(4r+5bI_1+5bk_1)]\end{matrix}\right\}}{M^3} - p^I d \equiv 0 \tag{16}$$

It is relatively easy to calculate the second differential of the net profit which is negative

$$\frac{\partial^2 N\pi_1}{\partial I_1^2} < 0 \tag{17}$$

The effect on the optimal investment *I* of changes in the various parameters in the model can be determined by taking the total differential of equation A2 and setting the appropriate partials equal to zero. For example, since

$$F(I_{1,t}; a, c, b, r, d, p^I, k_{1,t}, k_{2,t}, I_{2,t}) \equiv 0, \tag{18}$$

$$(\partial F/\partial I_{1,t})(\partial I_{1,t}/\partial a) + (\partial F/\partial a) = 0 \tag{19}$$

Solving for $\partial I/\partial a$ from equation A.4, we get

$$(\partial I_{1,t}/\partial a) = -F_a/F_{I_{1,t}} \tag{20}$$

The elements of all the total differentials can be calculated from equation A.2. We only list their signs below.

$F_{I_{1,t}} < 0$, $F_a > 0$, $F_b < 0$, $F_c < 0$, $F_r ?0$, $F_d < 0$, $F_{p^I} < 0$, $F_{k_{2,t}} < 0$, $F_{k_{1,t}} < 0$, $F_{I_{2,t}} < 0$.

The comparative statics for each of the other parameters can be easily determined similar to Eq. A.6.