Determinants of Container Ship Investment Decision and Ship Choice

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Abstract

Ship investment is one of the most complicated yet essential decisions vexing both existing and potential shipowners, due to market uncertainty and competition. This research applies choice models on observed ship investment data to examine shipowners' behaviour in making investment decisions and selecting specific ships. We found that ship investment increases with the growth rate of demand, but not of price. Preference for large ships is more sensitive to unit cost. The substitutability of new vessels with an equal-size used ship increases with ship size; for second-hand vessels, it decreases.

Keywords: Container ship; Capacity investment; Ship choice; Nested Logit Model

1. Introduction

Shipping is one of the world's most capital-intensive industries due to the high cost of purchasing a ship. A super post-Panamax vessel of 8,000 TEUs+, for example, costs about US$118 million (Dekker, 2006). Shipping companies have to pay a high capital cost, which often accounts for half of the total cost to run a large new ship. On the other hand, although second-hand ships are less expensive to purchase and hence require lower capital cost, they are not as efficient as new ships and they also lack varieties in the market. To achieve best scale efficiency, shipping companies may require different ship sizes for different trade routes. Two common issues faced by shipowners when they need to increase their capacity are: Should a shipping company order a new ship or purchase a second-hand one? What is the right size to purchase? It is not easy to address the two questions, and the situation can be more complicated due to the volatility and uncertainty of the container freight market.

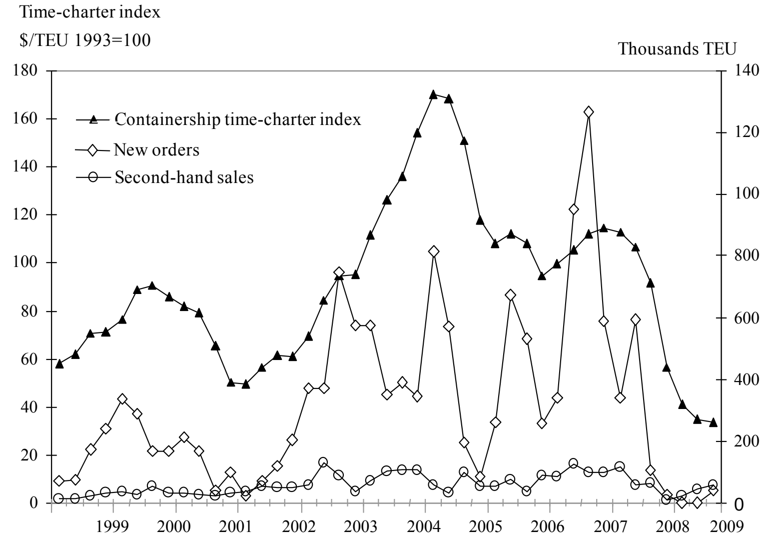

Figure 1: Container time-charter index and the demand for capacity from 1999 to 2009
Source: Clarkson Research Services Limited 2009

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The volatility of the container freight market is shown in Figure 1, which indicates the quarterly time-charter index for container ships from 1999 to 2009, and the demand for carrying capacity including the number of new orders and second-hand sales (in TEU slots). Motivated by the high freight rate, shipowners rush to order additional new vessels and expect to use them to improve operating efficiency, attract more customers, gain larger market share, and earn more profit (Luo et al., 2009) after delivery. Contrary to the expectation, the uncertain future demand and the collective behaviour of individual shipowners in capacity investment during the booming freight market only result in overcapacity in the shipping industry and low freight rate in the market. The market freight rate after the delivery is most likely not as high as expected. In this case, the high capital cost in running new ships may shake the financial ground of the shipping company.

Concerned about the possible low freight rate in the future, purchasing a second-hand ship may be a better decision as it needs less lead-time, so that the capacity can add to the running fleet to gain immediate profit increase. However, in the end, the higher operation cost of used ships and inefficiencies may make the shipping company not competitive enough. Moreover, the high periodical maintenance cost can also be a prohibitive burden to the shipping company.

In addition to satisfying the needs of the demand increase, decisions in shipping investment may also be made strategically, either to deter new entrants, or to compete with peers. This strategic behaviour in shipping capacity investment may add another dimension to the already complex environment for shipowners.

The difficulties in ship investment decision making, and the significant role of shipping capacity in both the private shipping business, and in international trade, maritime safety and environment (Luo et al., 2009), highlight the importance of studies about the behaviour in ship investment decisions. Compared with the volume of existing research on shipping freight rate (Beenstock & Vergottis, 1993; Tvedt, 2003; Kavussanos, 1996; Kavussanos, 1997; Veenstra, 1999; Tsolakis et al., 2003; Alizadeh & Nomikos, 2007; Merikas et al., 2008), there are relatively few publications for the analysis of ship investment decision making. Among the few publications, Fusillo (2003) modelled the excess capacity and tested whether shipping companies used excessive capacity to defend opportunistic rivals. However, the results from his random effects model show limited support for the entry deterrence hypothesis. Wu (2009) developed an economic model to calculate the optimal fleet capacity of representative container shipping lines in Taiwan, assuming cost minimization.

Bendall and Stent (2005) assessed ship investment under uncertainty, using ROA (Real Option Analysis) in an express liner service. None of these studies tried to reveal ship investment behaviour from the observed data on the ship investment and selection.

Outside of the shipping literature, capacity investment behaviour is a major topic in broader subject areas such as economics, game theory, and decision theory. Hay and Liu (1998) specified a model of oligopolistic investment behaviour, and tested it with panel data for manufacturing industries. They found that non-cooperative, cooperative, and competitive behaviours in capacity investment exist in different sectors. Gilbert and Lieberman (1987) revealed that there are both coordinative and pre-emptive investment behaviours in the chemical product industries. Wenders (1971), Spence (1977), Dixit (1979; 1980), Porter and Spence (1982), Reynolds (1986), and Haruna (1996) have each developed theoretical model on strategic capacity investment as a deterrent to entry or pre-emption of other firms' capacity expansion. Esposito and Esposito (1974), Hilke (1984), Lieberman (1987), and Driver (2000) also examined the existence of strategic investment behaviour in various industries in empirical studies.

Despite the existing literature on shipping market analysis or on the economic and game theory analysis for capacity investment behaviour, there has been no empirical research on shipowners' capacity investment and ship selection behaviour in the container shipping market. By applying discrete choice analysis on the observed data about ship investment and selection decisions for the container shipowners in the world, this paper reveals important factors that determine the decision on ship investment, and the choice of a particular ship type.

The paper is organized as follows. Section 2 first describes the theoretical analysis of the investment decision. Then it introduces the nested logit method to model the ship choice decision in the container shipping market.

Section 3 describes the data resource and the definition of the variables used in the analysis. Section 4 presents the empirical results of the logit models and discusses the shipowner's decision-making process. Section 5 concludes the study.

2. A theoretical model on the decision making process of ship investment

Ships are expensive assets in the maritime transportation, especially in the container shipping market. From the perspective of the shipowner or the shipping company, the basic investment decision is whether to invest at certain market conditions, be it to satisfy the market needs, or to deter the new entrant, or to compete with the peers. Irrespective of the motivations behind the decision, once the decision to invest is made, the next question is to consider whether ordering a new ship or buying a second-hand vessel is more suitable. The last decision is to decide on which specific type of ships to be bought according to the specific needs of the shipowner. The decision tree in Figure 2 depicts this decision-making process.

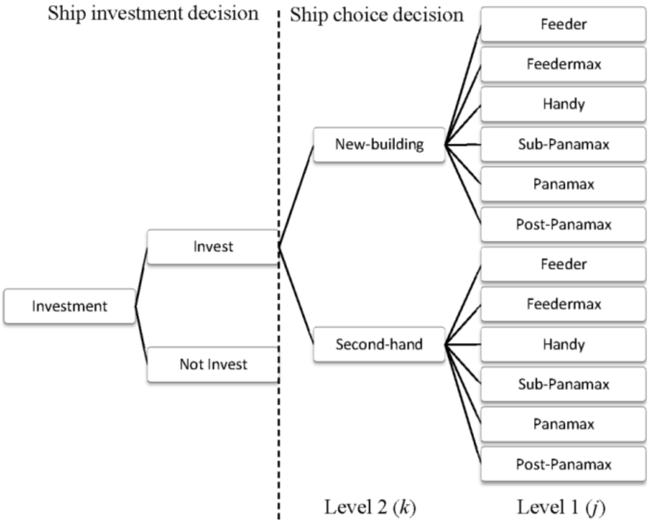

Figure 2 Shipowner's capital investment decision procedure

Figure 2 consists of two distinctive decision problems. The left part is the ship investment decision, which is different from the right part - the ship choice decision. The investment decision includes two choices – to invest or not to invest. If the decision is to invest, it leads to the ship choice decision; otherwise, there is no further decision to make. However, in the ship choice decision, there are an equal number of choices after selecting the new ship or second-hand one. Therefore, ship investment is a binary choice decision, while the ship choice decision is a multiple-choice problem. In this empirical analysis, the first problem is modelled using a binary choice logit model, and the second one is analyzed by applying a nested logit model.

2.1 Logit model for investment decisions

Assuming that there is no strategic behaviour in ship investment, the fundamental reason for a shipping company to increase its capacity is to meet the market demand. When the demand is increasing, the ship operator can increase the speed of the ship to satisfy the demand in the short-run. However, sailing fast is costly, and there is a certain limit on how fast a ship can sail. Therefore, the decision on whether to invest in capacity expansion depends on the demand, the existing capacity, and the impact of speed on cost, and freight rate. To illustrate the influence of such factors on the ship investment decision, we start from a very simple case where the company is running a fixed service between two ports.

2.1.1. Basic operation mechanism for a shipping fleet

Assume the shipping company has N identical container vessels of K TEU slots and it uses n vessels in a transportation activity. For each vessel, the operation cost is C and the layup cost is LC. The distance between two ports is L. The voyage cost $V(s)$ is an increasing function of ship speed s with positive increasing rate, that is, $V'(s)>0$ and $V''(s)>0$, following Beenstock & Vergottis (1993) and Stopford (2009). Using ρ for the average working hours of one ship in a year, the total number of trips a ship can make in a year can be written as $s\rho/L$. For simplicity, assume capital and financial costs are part of the operating cost C. Finally, the demand the shipping company faces is Q and the market freight rate is P.

Based on the above assumptions, the problem for the shipping company is to maximize its annual profit *w.r.t.* with respect to the number of ships in the active fleet n ($n \leq N$) and ship speed s , that is,

$$\max_{n,s} \pi = PQ - nC - ns\rho V(s)/L - (N-n)LC \qquad (1)$$

$$s.t.\ ns\rho K/L \leq 0 \text{ and } n \leq N.$$

Solving this problem using the Kuhn-Tucker method, we can get $ns\rho K/L=Q$. This implies that the shipping company will satisfy the demand using the number of active ships and adjusting the ship cruise speed.

Depending on the number of available ships, the shipping company can adjust the cruise speed according to the following two cases:

Case 1: $n < N$. In this case, $LC+sV'(s)s\rho C/L=0$, that is, the optimal vessel speed when there are layups in the company. Because shipping companies have enough capacity, they will normally not invest in acquiring additional vessels.

Case 2: $n = N$. In this case, the optimal speed is $s^*=QL/(N\rho K)$, that is, the shipping company has to increase the vessel speed to accommodate the increasing demand. However, due to the high voyage cost at high cruise speed, it is not always economical to run at high ship speed. In this case, the shipping company will have an incentive to purchase more ships, as long as the savings from the reduced speed can offset the incremental capital and financial cost, operation cost and voyage cost. Next, we analyze the condition for purchasing additional ships.

2.1.2. Factor analysis for ship investment facing demand increase

Facing a demand increase from Q to Q_H, the shipping company needs to increase vessel speed to $s_H=Q_HL/(N\rho K)$ to satisfy the demand. At this speed, the operating cost will increase to $V(s_H)$. However, with the additional vessel, the optimal speed could decrease to $s_{HI}=Q_HL/[(N+1)\rho K]$. Assuming that the ship cost is CK and the loan rate is d, if the annual marginal profit *w.r.t.* the number of ships can offset its marginal annual capital cost, that is, $\pi(N+1)-\pi(N)-dCK \geq 0$, it is better for the shipping company to buy the additional vessel.

Using y to denote this net marginal profit, through a series of simplification process, it can be written as

$$y=Q_H[V(s_H)-V(s_{HI})]/K-C-dCK. \qquad (2)$$

In theory, when $y>0$, the shipping company should purchase a ship; the larger the value y, the more likely the company will buy a ship. Clearly, the probability for the shipping company to purchase a ship increases with demand and the increasing rate of voyage cost *w.r.t.* ship speed, decreases with ship size, operating cost, and ship price.

In addition to the factors identifiable through theoretical analysis (Eq. 2), in practice, the expectation for future freight rate and shipbuilding lags strongly affect the capacity investment decision. Because expectation is not observable, it can be approximated by the demand growth (GQ) assuming that an individual's expectation is based on the past market performance. An increasing demand will increase the probability for the shipowner to invest in capacity, while a decreasing market will suppress the investment intention of the shipowner (Luo et al., 2009).

Lastly, the strategic behaviour in capacity competition adds another dimension to the complex decision making process for ship investment. Shipping companies with different market power may have different strategies facing different market structure. Larger dominant companies could invest excessive capacity to prevent new entrants, or to expel existing smaller companies. In a competitive market, an existing company has to follow the capacity growth of its peers in order to keep its market share. Within shipping alliances, the members may take turns to invest in order to avoid overcapacity in a specific route. The capacity investment behaviour of the peers ($OINV_{it}$) also plays an important role in the decision making process of capacity investment.

In summary, the investment decision of the shipping company *i* at time *t* can be expressed as a function of the observable variables discussed above, and an unobservable part, the random error ε_{it}, that is,

$$Y_{it}=y_{it}+\varepsilon_{it} \qquad (3)$$

where $y_{it}=f(Q_t, GQ_t, K_{it}, CK_{it}, OINV_{it})$, and Y_{it} takes value 1 if invest, 0 if not. Assuming that ε_{it} is an independently and identically distributed (*iid*) extreme value, the shipowner's capacity investment behaviour can be modelled using a binary choice logit model (Green, 2003). To test the different investment strategies, we also estimated the model for new entrants and incumbents separately, in addition to the general model that does not distinguish them. If entry deterrence or pre-emptive strategies exist, there should be different responses to the demand and competition, which can be detect using the statistical test.

2.2 Nested logit model for ship choices

The second decision in the ship investment process, as shown in the right part of **Error! Reference source not found.**, is the selection of ship types. To analyze shipowners' behaviour in selecting a ship type, a nested logit model (Mcfadden, 1978; Mcfadden, 1980; Green, 2003) was adopted, based on two important observations:

1. Shipping companies selecting a used ship often have urgent needs for the ship. Ordering a new ship may take too long. Therefore, the decision for used ones or new ones is at a higher level.
2. Ships in the same category, or nests (used or new), are more substitutable. If a shipping company cannot find a specific vessel type in the second-hand nest, most likely it will find another type of second-hand ships for replacement.

The traditional logit model is inappropriate because it cannot satisfy the *IIA* (Independence from Irrelative Alternatives) requirement (Train, 2003), while the nested logit model only requires *IIA* for the alternatives in the same nest, not in different nests.

The nested logit model follows the standard specification by (Train, 2003). Mcfadden (1978) has shown that the estimated coefficient on the inclusive variable should be between 0 and 1. Otherwise, the assumption on the nest structure is inappropriate. Therefore, we use this property to test if the proposed nested structure in **Error! Reference source not found.** is appropriate. Furthermore, if the model is appropriate, it is expected that the substitutability between the ships within the same nest should be larger than that in different nests.

3. Data description

3.1. Data for the investment decision model

Lloyd's Fairplay maintains a ship registration database that contains detailed records about the owner, order and delivery date, and ship transaction information for over 120 thousand vessels over 100 GT, of which 5724 are container vessels owned by 926 shipowners as of January 1, 2009. These data, together with the market data at the time of the transaction, are fitted into a binary choice model to explore the ship investment decision from 1999 to 2008. A separate analysis is carried out for the incumbents and new entrants, to examine possible different behaviour between them. The variables used in the model are explained next.

$NINV_{it}$, $EINV_{it}$ and INV_{it} : Three binary dependent variables represents the investment decision of new entrants, existing firms, and all firms respectively.

$THROU_t$ and $GTHROU_t$: Two variables used to examine how demand changes the investment decision. The former is the global container throughput in million TET, and the latter is its growth rate.

K_{it} : The total capacity (in thousand TEU) of firm *i* at the beginning of year *t*. It is calculated backward from each shipowner's capacity on January 1, 2009, using the equation $K_{it-1}=K_{it}-ADD_{it}+SELL_{it}+SCRAP_{it}$, where ADD_{it} is the delivery of new ships and purchase of second-hand ships, $SELL_{it}$ is the selling of second-hand ships. These two values are from Lloyd's Fairplay database. $SCRAP_{it}$ is the scrapping of used ships obtained from CSIN (Clarkson's Shipping Intelligence Network) from 2004 to 2008. Ship scrapping before 2004 is ignored because the data are not available. However, this will not affect regression results because the total demolition from 1999 to 2008 only accounts for 0.5 percent of the total container carrying capacity (Drewry annual report). For new entrants, K_{it} equals 0.

$AVGK_{it}$: The average vessel size (in thousand TEU) of firm *i*, defined as the total capacity divided by the number of vessels of the firm.

$TCMI_{it}$: The time-charter index for container ships. If a firm invests in any ships, $TCMI_{it}$ is the monthly average time-charter index at the month when the ship is ordered or bought. If not, $TCMI_{it}$ is just the time-charter index of that year. $GTCMI_{it}$, $NBPMI_{it}$, and $SEPMI_{it}$ are the growth rate of time-charter index, new-building price index and second hand price index, calculated in the same way. These data are from Clarkson Research Services Limited 2009.

$OINV_{it}$: The capacity investment rate of all other firms, defined as $OINV_{it}=\sum_{i\neq i} KINV_{lt} / \sum_{l\neq i} K_{lt}$, where $KINV_{lt}$ is the actual capacity invested by firm *l*. It is designed to examine how a shipowner responds to the capacity investment of the competitors.
Finally, the two variables, $ONFINV_{it}=\sum_{i\neq i} KINV_{lt}\times NINV_{it} / \sum_{l\neq i} K_{lt}$, $OEFINV_{it}=\sum_{i\neq i} KINV_{lt}\times EINV_{it} / \sum_{l\neq i} K_{lt}$, are defined to capture the different responses to the investment of new entrants and the existing ones. $ONFINV_{it}$ represents all other new entrants' capacity investment ratio, and $OEFINV_{it}$ represents all other incumbents' capacity investment ratio.

3.2. Data for the ship choice model

The data used for ship choice model include the observed ship-selection records for shipowners who ordered new ships or bought second-hand vessels from 1998 to 2008. It involved 858 companies and 4963 vessels, with 64 percent new buildings (10.4 million TEU) and 36 percent second-hand vessels (5.8 million TEU). These variables are explained next.

$CHOICE_{ij}$: The binary dependent variable represents a firm's choice on ship type j: it equals to 1 if the firm selects ship type j; otherwise, 0.

$FEEDER_i$, $FEEDERMAX_i$, $HANDY_i$, $SUBPANAMAX_i$, $PANAMAX_i$, $POSTPANAMAX_i$: The dummy variables indicate different types of container vessels.

NEW_i and $SECOND_i$: dummy variables for new or second-hand ships respectively. K_{it}, $THROU_t$, and $GTHROU_t$ are the same as those defined in the investment decision model.

TC_{jt}, GTC_{jt}, NBP_{jt}, and SEP_{jt} are the time-charter rate and its growth rate, the newbuilding price and the second-hand price for vessel type *j* at year *t*.

$UINVC_{ijt}$: The unit investment cost, defined as $UINVC_{ijt}=[NEW_{ij}\cdot NBP_{jt}+SECOND_{ij}\cdot SEP_{jt}] / TEU_{ijt}$, where TEU_{ijt} denotes the size of the ship. This definition ensures that the $UINVC_{ijt}$ is specific to each firm *i*, each ship type *j*, and each nest *k*.

The last variable $CONLAG_{ijt}$ is the actual shipbuilding lag for the selected vessel type. For the un-chosen types, it is the average construction lag of that type. For second-hand vessels, the construction lag is 0.

4. Results and discussion

Following the decision making process, we first present and explain the results from the binary choice model, and then the ship choice behaviour using the results from the nested logit model.

4.1 Model results for the ship investment decision

To analyze the investment behaviours for different shipowners, four models were applied to different sample data and the results are shown in **Error! Reference source not found.**. Models 1 and 2 are designed to analyze the investment behaviour of all shipowners. Comparing with model 2, model 1 has two extra variables: the existing capacity (K_{it}) and average ship size ($AVGK_{it}$), used to test their impacts on the investment decision. Comparing with model 2, models 3 and 4 are for existing firms and new ones respectively. **Error! Reference source not found.**1 also provides the t-values for the null hypothesis $H_0 : \beta_i^{m3} = \beta_i^{m4}$, that is, the coefficients are the same for the corresponding variables of models 3 and 4.

Table 1 Results from binary choice models for ship investment decisions

	(1)	(2)	(3)	(4)	
Dep. Var.	INV_{it}	INV_{it}	EINV_{it}	NINV_{it}	$H_0 : \beta_i^{m3} = \beta_i^{m4}$
C	-7.411^{**}	-7.145^{**}	-7.004^{**}	-7.885^{**}	2.199^{*}
THROU_t	0.003^{*}	0.003^{*}	0.002	0.003	-591.001^{**}
GTHROU_t	5.038	6.554^{*}	1.772	10.699^{*}	-0.492
K_{it}	0.018^{**}				
AVGK_{it}	-0.069^{**}				
NBPMI_{it}	0.031^{**}	0.029^{**}	0.033^{**}	0.014	192.45^{**}
TCMI_{it}	-0.003	-0.002	-0.003	0.001	-261.77^{**}
GTCMI_{it}	-3.016^{**}	-3.034^{**}	-2.207^{**}	-3.288^{**}	16.51^{**}
ONFINV_{it}	116.848^{**}	107.01^{**}	80.759^{**}	119.325^{**}	-0.094
OEFINV_{it}	-4.595^{**}	-4.638^{**}	-3.249^{**}	-5.053^{**}	2.171^{*}
Observation	10186	10186	10186	10186	
Log likelihood	-3448	-3699	-2798	-2111	
Probability(LR stat)	0.000	0.000	0.000	0.000	

Note: * *Significant at the 0.05 level;* ** *Significant at the 0.01 level, two-tailed test.*

Almost all the coefficients shown in Table 1 were significantly different from zero. The coefficients on $THROU_t$ and $GTHROU_t$ for all the 4 models were positive, indicating the positive impact of high market demand on the investment decision for both new firms and existing ones. The positive coefficient for K_{it} suggests that the larger firms are more likely to invest; and the negative estimate on $AVGK_{it}$ indicates that shipping companies with larger ships have lower probability for investment.

Because the new building price ($NBPMI_{it}$) is highly correlated with second-hand price, only the new building price is included to represent the price in both markets. The estimation result shows a high statistical relationship between the ship price and the likelihood for the shipowner to acquire additional ships. This is because the ship price increases with the increase in demand for ships.

$TCMI_{it}$ and $GTCMI_{it}$, the time-charter rate and its increasing rate, approximated the freight rate in the container shipping market. While $TCMI_{it}$ is not an important factor for ship investment decisions, $GTCMI_{it}$ has negative impacts on the probability of investment. Possibly, because freight rate is volatile and uncertain, shipowners may associate the high increasing rate with high risk. Therefore, they may hesitate to invest at high $GTCMI_{it}$.

The last two variables, $ONFINV_{it}$ and $OEFINV_{it}$, capture the response of capacity investment to the new entrants' investment ratio and that of incumbents. The positive coefficient of $ONFINV_{it}$ indicates a high probability of investment when the container shipping industry sees many new entrants: a sign for the blooming market, which will definitely encourage investment. This also explains the negative coefficients for $OEFINV_{it}$: according to their definition, $OEFINV_{it}$ and $ONFINV_{it}$ are complements.

The t-values in the last column of Table 1 reveals that the investment decisions between the incumbents and new entrants were significantly different over a set of factors, namely the changes in demand ($THROU_t$), investment cost ($NBPMI_{it}$), and the changes in time-charter rate ($TCMI_{it}$ & $GTCMI_{it}$). In addition, their responses to the incumbents' investment ($OEFINV_{it}$) were also statistically different: although their investment both decreased, the new entrants decreased more than the existing ones did. This may imply the existence of market barriers in container shipping: new entrants need to overcome more hurdles to acquire a container vessel than incumbents do. Finally, their responses to the investment of the new entrants ($ONFINV_{it}$) showed no significant statistical difference. This suggests that the incumbent firms have no intention to pre-empt new comers.

4.2 Model results from the ship selection decision

Having determined to expand the capacity, the next decision facing a shipowner is which ship to choose: a new ship or a second-hand one, a large ship or a small one, following the decision tree in Figure 2. Table 2 presents the results from the nested logit model.

Table 2 Results from the nested logit model for ship choice decisions

Parameter	Coefficient	Standard Deviation	t-Value	P-Value
FEEDER_L1	-9.961^{**}	0.366	-27.200	<.0001
FEEDERMAX_L1	-5.340^{**}	0.284	-18.830	<.0001
HANDY_L1	-1.392^{**}	0.192	-7.240	<.0001
SUBPANAMAX_L1	-1.031^{**}	0.108	-9.580	<.0001
PANAMAX_L1	-0.304^{**}	0.051	-5.960	<.0001
UINVC_L1	-394.097^{**}	8.974	-43.910	<.0001
TC_L1	0.153^{**}	0.011	13.560	<.0001
GTC_L1	-0.386	0.623	-0.620	0.535
NEW × CONLAG_L2G1	1.036^{**}	0.205	5.050	<.0001
NEW × K_L2G1	0.001^{**}	0.000	3.290	0.001
NEW × GTHROU_L2G1	-2.149^{**}	0.718	-2.990	0.003
NEW × NBP_L2G1	0.076	0.056	1.350	0.177
SECOND × SEP_L2G1	0.215^{**}	0.068	3.150	0.002
INC_L2G1C1	0.306^{**}	0.049	6.220	<.0001
INC_L2G1C2	0.242^{**}	0.058	4.170	<.0001
Number of Observations	4933			
Number of Cases	59196			
Chi-Square	8218.8			
Log Likelihood	-8149			

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

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

The coefficients of the inclusive variables (INC_L2G1C1 and INC_L2G1C2) were between 0 and 1, indicating that the nest structure is consistent with shipowners' ship choice behaviour: shipowners will first decide to buy a new vessel or a used one before considering the size of the ship.

With Post-Panamax (the largest vessel) as the reference choice, the negative coefficient for each ship type means that the possibility to choose that ship-type is lower than the largest vessel. The coefficients increased from the smallest vessel (feeder vessel, -9.961) to the largest (Panamax. -0.3), showing preference increase with ship size. This trend reflects shipowners' continuous pursuit of scale economy offered by large container ships.

The negative coefficient of *UINVC* suggests that high cost per TEU reduces the preference for that ship type. On the revenue side, the positive coefficient on *TC* indicates the high preference for ships with higher time-charter rate. This result is consistent with shipowners' profit maximizing behaviour in ship choice. The estimated coefficient is not significant for the variable *GTC*, indicating that the growth rate of the market price does not affect ship choice.

The coefficients for the interactive variables reveal the preference over new vessels or second-hand ships for five variables, namely the shipbuilding lag, the existing capacity of the shipping company, demand growth rate, the newbuilding price and the second-hand price. The results are explained below:

1. The positive coefficient for NEW×CONLAG implies that the longer the shipbuilding lag, the higher the preference for new ships: larger vessels that take longer time to build can provide better economy of scale.
2. The positive coefficient for NEW×K indicates that shipping companies with larger capacity prefer new vessels. Such companies have probably been in the business for a long time and have a long-term plan for capacity expansion. Therefore, they can place new orders according to their future capacity needs. Even with the unexpected market fall, they can retire the old ships to increase fleet efficiency.
3. The coefficient for NEW×GTHROU was negative and significant, indicating that new ships are not as attractive as used ones when the demand growth rate is high: comparing with new ships, second-hand ships can meet immediate market demand and earn quick revenue.
4. The coefficient for NEW×NBP was not significant, indicating that the price of new ships is not a critical factor in ship selection behaviour: most shipping companies decide to order new ships not for their low price, but for the high market demand.
5. Lastly, the positive significant coefficient on SECOND×SEP uncovers the nature of the second-hand market: the high price is a result of the high preference.

Having explained the impacts of individual variables on the ship selection behaviour, we demonstrate how a change in one variable affects the preferences of ship types, including the same ship types and the different types in the same nest, and those in different nests. Such analysis is particularly helpful to understand the ship selection behaviour of the shipowners. For example, we may want to know the change to the probability of selecting each ship type if the unit investment cost (*UINVC* in section 3.2) for a new Panamax container vessel increases by 1 percent. Based on Green (2003), the elasticity of selecting a ship type j in nest k for an attribute change of ship type j^* and nest k^* ($\eta^{jk}_{j^*k^*}$) is:

$$\eta^{jk}_{j^*k^*} = \frac{\partial \ln prob(j,k)}{\partial \ln x_{j^*k^*}} = \left[1_{k=k^*} \cdot (1_{j=j^*} - p_{j|k}) + \tau_k (1_{k=k^*} - p_k) p_{j|k}\right] \beta_x x_{j^*k^*} \qquad (4)$$

where $x_{j^*k^*}$ is the changing variable, and β_x is its coefficient. This elasticity has three different cases: (*a*) own-elasticity: the elasticity for the ship type with an attribute change; (*b*) cross-elasticity: the elasticity for different ship types in the same nest; and (*c*) cross-nest elasticity: the elasticity for the ship that belongs to a different nest:

$$\eta^{jk}_{j^*k^*} = \beta_x x_{j^*k^*} \times \begin{cases} [(1 - p_{j^*|k^*}) + \tau_{k^*}(1 - p_{k^*}) p_{j^*|k^*}] & \cdots\cdots j = j^* \; and \; k = k^* \quad (a) \\ [-p_{j^*|k^*} + \tau_{k^*}(1 - p_{k^*}) p_{j^*|k^*}] & \cdots\cdots j \neq j^* \; and \; k = k^* \quad (b) \\ -\tau_{k^*} p_{k^*} p_{j^*|k^*} & \cdots\cdots j \neq j^* \; and \; k \neq k^* \quad (c) \end{cases} \qquad (5)$$

Clearly, for a variable change of a specific ship type, the cross-elasticity is the same for other ship types in the same nest (from 5-b), which is different from the cross-nest elasticity (from 5-c). This is due to the relaxed *IIA* requirement of the nested logit model: it only requires IIA for the types in the same nest, not across different nests. In other words, if the unit cost for a new feeder vessel increases, the IIA only requires that the probability for shipowners to choose other new container vessels will increase by the same proportion. It does not require that the probability to choose second-hand container vessels also increase by the same proportion.

To demonstrate the actual probability changes revealed in the current ship selection behaviour, we calculated the elasticity for all the ship types in both new and second-hand ships *w.r.t.* the unit cost of each ship type, which is shown in **Error! Reference source not found.**.

Table 3 Ship selection elasticity with respect to the unit cost of each ship type

Effect on	NFeeder	NFeedermax	NHandy	NSubpanamax	NPanamax	NPostpanamax
NFeeder	-2.709	1.282	1.694	0.679	1.137	0.166
NFeedermax	1.053	-4.676	1.694	0.679	1.137	0.166
NHandy	1.053	1.282	-8.505	0.679	1.137	0.166
NSubpanamax	1.053	1.282	1.694	-14.023	1.137	0.166
NPanamax	1.053	1.282	1.694	0.679	-18.020	0.166
NPostpanamax	1.053	1.282	1.694	0.679	1.137	-30.524
SFeeder	0.034	0.111	0.206	0.100	0.185	0.030
SFeedermax	0.034	0.111	0.206	0.100	0.185	0.030
SHandy	0.034	0.111	0.206	0.100	0.185	0.030
SSubpanamax	0.034	0.111	0.206	0.100	0.185	0.030
SPanamax	0.034	0.111	0.206	0.100	0.185	0.030
SPostpanamax	0.034	0.111	0.206	0.100	0.185	0.030
Cross-nest ratio	30.97	11.55	8.22	6.79	6.15	5.53

Effect on	SFeeder	SFeedermax	SHandy	SSubpanamax	SPanamax	SPostpanamax
NFeeder	0.179	0.215	0.285	0.114	0.149	0.202
NFeedermax	0.179	0.215	0.285	0.114	0.149	0.202
NHandy	0.179	0.215	0.285	0.114	0.149	0.202
NSubpanamax	0.179	0.215	0.285	0.114	0.149	0.202
NPanamax	0.179	0.215	0.285	0.114	0.149	0.202
NPostpanamax	0.179	0.215	0.285	0.114	0.149	0.202
SFeeder	-1.612	0.866	1.279	0.583	0.880	1.193
SFeedermax	0.618	-2.909	1.279	0.583	0.880	1.193
SHandy	0.618	0.866	-5.576	0.583	0.880	1.193
SSubpanamax	0.618	0.866	1.279	-8.865	0.880	1.193
SPanamax	0.618	0.866	1.279	0.583	-11.345	1.193
SPostpanamax	0.618	0.866	1.279	0.583	0.880	-11.032
Cross-nest ratio	3.45	4.03	4.49	5.11	5.91	5.91

Note: the prefix ‘N’ and ‘S’ refer to the new-building and second-hand groups.

Error! Reference source not found. contains two parts. The upper part is the elasticity for the unit cost change of new vessels, while the lower part is that of second-hand vessels. The last row at each part is the cross-nest ratio, defined as the ratio between cross-elasticity and cross-nest elasticity. Each column holds the elasticity for a unit cost change in one ship type identified by the table header. For example, the first column is the elasticity for the unit cost change of new Feeder vessels, and the last column is that for new Post-Panamax vessels. This table exhibits several interesting properties:

1. For a unit cost increase of any ship types, the own-elasticity is always negative, while cross-elasticity is always positive. For example, the own-elasticity of new feeder vessels (first row, first column) is -2.709, while the cross-elasticity in the upper part of the first column is 1.03. The negative elasticity indicates an inverse relationship between demand and its price: shipowners’ preference for a specific ship-type will decrease with the price of that ship-type. The positive elasticity shows the substitutions between different vessel types: the cost increase of one ship type will increase the demand of the other vessel types.
2. The cross-elasticity is always higher than cross-nest elasticity. This reflects the higher substitutability among the ships in the same nest, than that in a different nest. If the cost of one new ship type increases, shipowners will be more likely to select other new vessels than second-hand ones. Similarly, they will select other second-hand vessels for a cost increase in used ones.
3. Generally, the larger the ship size, the higher the absolute value of the own-elasticity. This indicates that the demand for large ships is more sensitive to the unit cost than the smaller ones.
4. The cross-nest ratio for new ships decreases with ship size, indicating the higher substitutability for larger new container vessels: the larger second-hand ships are relatively newer than the smaller used

ships; therefore, they are closer to new ships than the smaller ones. On the other hand, the cross-nest ratio for second-hand ships increases with the ship size, implying the lower substitutability of large second-hand container vessels using the new ones of the same size: larger new container vessels cost higher and take longer time to build.

To summarize, the empirical results presented in this section reveal how shipowners make ship investment decisions, and how they select the type of ships to suit their own needs. In making ship investment decisions, firstly, the demand growth rate is a major positive contributor, while the growth of time-charter rate, as an indicator for market price, holds back the investment. Secondly, consistent with the theoretical analysis, larger companies will invest more often, while the companies with bigger ships will invest less frequently. Thirdly, high investment from new firms (hence low investment from incumbents) is a good indicator for booming markets, which significantly increases the probability of investment for all firms, new or existing. Fourthly, contrary to theoretical analysis, high new building price does not reduce the probability of ship investment; instead, it has a significant positive relationship with ship investment. Finally, there is no significant difference between new entrants and the existing companies in response to the investment of new entrants: evidence showing no pre-emptive capacity in the container shipping industry.

The nested logit model for ship choice behaviour reveals the preferences of the investors over different kinds of ships, used or new, small or large, from three different aspects. First, from the perspective of individual variables, the coefficients on the inclusive variables indicate that the assumption on the decision-making process for ship selection (as described in Figure 2) fits the actual decision process of the ship investors. Also, larger vessels are preferred than the smaller ones; ships that can bring larger profit (higher time-charter rate and lower unit cost) are highly preferred. Secondly, new ships are preferred if the shipbuilding lag is long, or if the company has larger capacity; they are not preferred when the growth rate of demand is high, and the preference for new or second-hand ships is not related to the new building price, a typical situation in a derived market. Finally, larger vessels are more sensitive to their own cost change than smaller ones; cross-elasticity is always higher than cross-nest ones. Large second-hand ships are better substitutes to large new vessels than smaller ones, while smaller new vessels are closer substitutes to used ones.

5. Summary, conclusion and discussion

This article presents an empirical analysis that reveals shipowners' behaviour in making ship investment decisions and selecting ship types. It starts with a theoretical analysis to identify the important factors in capacity investment for a simplistic, profit-maximizing firm with a fleet of equal-size vessels operating between two ports and facing increasing demand. From the assumption on the decision-making process of ship investment and selection, two logit models were selected: binary choice model for the investment decision, and nested logit model for the ship selection decision. Ship investment data, including all the container ships over 100 gross tons in the Lloyd's Fairplay ship registry database before January 1, 2009, was employed in this analysis. This data involves 5724 container vessels and 926 shipowners. Both models and most of the coefficients were highly significant. The results can largely explain the underlying behaviour in the ship investment decisions and ship choices.

For ship investment decisions, the results show that shipowners mainly focus on the real demand growth: they are cautious about the high growth rate in the market price due to its volatility and uncertainty. Although larger shipowners tend to invest more, shipowners with bigger vessels tend to invest less. There is no obvious difference between existing firms and the new entrants in responding to competitors' investment: their investment will both increase with the new entrants' investment, and will decrease with the incumbents'.

The empirical results also support the assumption about the decision making process of ship choice: shipowners first decide to purchase a new ship or a second-hand one, then the size of the ship. Generally, they prefer larger vessels and the vessels that maximize profit (higher time-charter rate and low unit cost), regardless of new or second-hand ships. New vessels are preferred when the shipbuilding lag is long (indicating larger ships), not when the demand increasing rate is high. Companies with large capacity prefer new ships. Finally, the preferences of larger vessels, both for new and second-hand vessels, are more sensitive to the change in the unit cost. For new ships, larger vessels have higher substitutability, while the smaller vessels do for second-hand vessels.

This research does not have detailed data on the specific route that the ship is deployed. Therefore, the results obtained in this research are applicable to the global scale. Some of the results, such as the strategic behaviour in capacity investment, may not be necessarily applicable when a specific route or region is considered. Nevertheless, the results from this research can provide insights into how existing shipowners worldwide make ship investment decisions, which can benefit the global shipping companies, the financial investors, or maritime administrations in the decision making process.

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