The Hong Kong Polytechnic University

Department of Logistics and Maritime Studies

ECONOMETRIC ANALYSES OF CONTAINER SHIPPING MARKET AND CAPACITY DEVELOPMENT

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CERTIFICATE OF ORIGINALITY

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ABSTRACT

There has been a tremendous growth in international trade and the associated growth in containerized shipping in the last two decades. Coincide with this growth the container liner shipping market has become more volatile and concentrated. This is contributed by the uncertainties in the world economic development, and carriers' pursuit of scale economies and larger market shares. While these issues have attracted considerable attention in the container liner shipping industry, few studies focus on market fluctuations and the decision factors for liner companies' capacity expansion. This motivated the research in this dissertation that consists of a dynamic market analysis, and an examination of carrier capacity expansion and ship investment behavior in the container liner shipping market.

The dynamic market analysis models the fluctuation of the container freight rate using two dynamic equations: a price dynamic equation that is determined by market demand and supply, and a fleet capacity dynamic equation that models the behavior of profit-maximizing firms. These two dynamic equations are estimated using the world container shipping market statistics from 1980 to 2009, applying the method of three-stage least squares. The estimated parameters of the model are statistically significant, and the overall explanatory power of the model is above 78%. The short-term in-sample prediction of the model largely replicates the container shipping market fluctuation in terms of the fleet size dynamics and the freight rate fluctuation in the past 29 years. The prediction of the future market trend suggested that the container freight rate

would start to recover from 2010, which indeed happened in the container shipping market. This is the first dynamic-economic model for container shipping market with high predication power.

The capacity expansion behavior of individual carriers are examined using a panel data set comprised of the capacity information of the top 100 liners in the world from 1999 to 2009. Among the top 10 carriers, companies with expanding market shares grow faster, while those with shrinking market shares expand slower. This suggests greater concentration in the future. Carriers in the top 20 list grow faster than the others when facing capacity expansions of all other carriers. Finally, the results also point to the rule of mergers and acquisitions in fueling company capacity growth. As the first study linking market concentration with the growth of individual carriers quantitatively, it can helps policy makers identify appropriate strategies to prevent market concentration and maintain a high level of economic efficiency in container shipping.

Finally, this dissertation also explores the determinants of ship investment decisions as well as decisions of ship choice. Firms make a decision to invest or not, and then they select a specific ship. When carriers select a ship, they are found first to choose whether to invest a new or second-hand ship and then to choose the size of the ship. This research found that new ships are preferred to second-hand ones. However, when the shipbuilding lag is long, or the demand growth rate is high, this preference decreases. Larger new ships are preferred to smaller ones. For second-hand vessels, handysize is the most preferred ship size.

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GLOSSARY

2SLS-Two-stage Least Squares

3SLS-Three-stage Least Squares

CL-Conditional Logit Model

DWT-Dead Weight Tonnage

FGLS-Feasible Generalized Least Squares

GLE-Generalized Least Squares

IIA-Independence from Irrelevant Alternatives

IV-Instrumental Variable

KKT-Karush-Kuhn-Tucker Condition

LIML-Limited Information Maximum Likelihood Estimation

LR-Likelihood Ratio

M&A-Mergers and Acquisitions

MLE-Maximum Likelihood Estimation

ML-Multinormial Logit Model

NL-Nested Logit Model

OLS-Ordinary Least Squares

TC-Time Charter Rate

TEU-Twenty-foot Equivalent Unit

Chapter 1: Introduction

Within the short history of containerization, transportation of containerized goods by sea has significantly increased trade between nations with different comparative economic advantages. Specialization and technological progress have boosted the efficiency in global shipping and port operation in the past two decades, making container transportation indispensable for global trading firms to thrive in the increasingly competitive economic environment. Recent statistics show that, whereas world seaborne trade doubled from 3,615 million tons in 1985 to 8,373 million tons in 2010, containerized trade increased more than eight times within the same period, from 160 million tons to 1,347 million tons (Clarkson PLC, 2011). This demonstrates the increasingly important role of container transportation and its contribution to the global economy. However, a review of shipping related literature reveals that the container shipping market and liner companies' capacity development have been least studied. In this thesis, market capacity movement and individual companies' capacity expansion and investment behavior are studied in a wide context from an economic perspective, using econometric methodologies.

This chapter first gives an overview of the container shipping market, including its evolution and development. It then stresses two issues - market concentration and the cyclical nature of the container market. After that, the research questions and objectives of this thesis are stated, followed by an outline of the thesis.

1.1 Overview of the container market

To help understand the background to this thesis, it is necessary to first introduce relevant information about the evolution of the container shipping industry and its development. This also demonstrates the important role that containerization plays in world trade, and helps to identify two major concerns over container transport: market concentration and the cyclical nature of the freight market.

1.1.1 Evolution of container shipping industry

During the nineteenth century, as canals, railways and steamships merged into a global transportation network, the shipping industry experienced more changes than that in the previous two millennia. The steamship technology made it possible for shipowners to offer scheduled services with multi-deck vessels, which is called cargo liners. The cargo liner service was flexible in carrying a mixture of manufactures, semi-manufactures, minor bulks and passengers etc. However, the ship loading and unloading of general cargo as break-bulk cargo (on pallets or in barrels) was a slow, labor-intensive process. In the late 1950s, 60-75% of the cost of transporting cargo by sea was incurred in port; today, under ocean containerization, this percentage has been reduced to 37% of the total seaborne costs (Levinson, 2006).

The advent of container transportation appeared in the 1950s – pioneered by a US businessman, Malcolm McLean, the owner of a trucking firm. In 1955, he bought the Pan Atlantic Tanker Company and adapted its ships to carry truck trailers on their decks using containers. On April 26, 1956, he launched the world's first seaborne containership that sailed from New Jersey to Houston in the US. Malcolm Mclean later renamed his company Sea-Land, and started the first Trans-Atlantic containerization service, its maiden voyage sailing from its newly constructed terminal in New Jersey to McLean's new trailer terminal in Rotterdam. With the advent of standardized containers, the intermodal transportation of international trade had begun to be revolutionized.

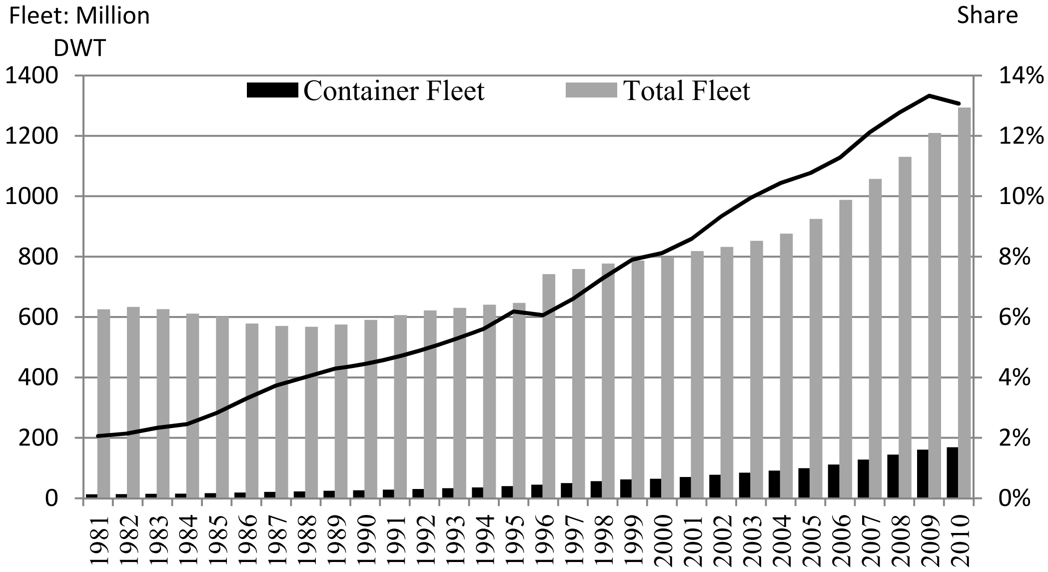
The containerization of maritime transportation was remarkable in reducing port time. With comparable services, the port time of a containership was reduced to just 17% of that of the cargo liner (Stopford, 2009, p.511). In addition to reducing port time, container transportation has also changed the way liner companies operate (Stopford, 2009, p.511). 'Door-to-door' service has become an essential part of container transportation services. The need to manage both the land and sea legs of transport has further stimulated the development of intermodalism. Containerization has also led to consolidation, and consequently, the liner shipping industry becomes the most concentrated sector, and this is further investigated in the next section. Finally, because container ships could not switch between liner and bulk, the tramp market for ships carrying containerized cargo disappeared. Minor bulk cargo liners moved into specialist vessels, such as open hatch bulk carriers, parcel tankers, car carriers, MPP (Multipurpose vessel) vessels and heavy lift ships.

In addition to the effects on the shipping industry, there have been even more profound effects on the world economy. Containerization has made the transport between various regions fast, reliable, and cheap. In 2004, packing 4,000 video-recorders into a container reduced the freight cost from the Far East to Europe to around 83 cents per unit (Stopford, 2009, p.512). As a result, distance and transport cost becomes a less important consideration within the manufacturing industry.

1.1.2 Container market development

Since its advent in the 1950s, the container has become an indispensable part of maritime transportation. It is a remarkable innovation that has had a tremendous impact on both production and distribution (Levinson, 2006). There is no doubt about the impact of containerization on driving supply chain efficiency, reducing costs and paving the way for global trading. On the other hand, the booming world economy has also contributed to the development of the container fleet. From 1981 to 2010, the total world fleet increased from 626 to 1,294 million DWT, while during the same period the container fleet increased from 13 to 169 million DWT. The cargo carrying capacity increased from around 2% to 13% of the world fleet during the same period (Figure 1-1).

Figure 1-1: World container fleet development from 1981 to 2010



Data source: Shipping Review and Outlook (2011).

The lower rates of ocean container transportation versus those of break-bulk transportation have been a major factor contributing to the significant growth in the world trade of general cargo. In 1984, the world seaborne trade transported in containers by water carriers was 148 million tonnes, increasing to 1,347 million tonnes in 2010 (Clarkson PLC, 2011). As of 2007, 50% of international cargo transported by water carriers was containerized (Notteboom & Rodrigue, 2008). Table 1-1 presents the degree of containerization in certain European ports from 1980 to 2005, which is the ratio of containerized cargo to total general cargo handled by a port. By 2005, in some large ports the containerization degree was over 90%, such as at the ports of Hamburg, La Spezia and Le Havre.

Table 1-1: Degree of containerization in a selection of European ports (%)

Port	Country	1980	1985	1990	1995	2000	2003	2005
Hamburg	Germany	32	42.6	66.2	81.7	93.1	95.4	96.4
La Spezia	Italy	34.4	40.3	76.1	88	90.3	93.2	93.2
Le Havre	France	58.9	67.7	71.2	66.8	80.4	86.9	90.3
Algeciras	Spain	71.8	69.4	70.8	79.2	88.5	89.4	89.7
Leixoes	Portugal	22	28.7	37.1	63.5	75.4	85.1	87.7
Rotterdam	The Netherlands	57.4	65.8	69.9	73.9	77.7	79.1	83.1
Bremerhaven	Germany	35.6	47.1	58.7	73.4	81.9	82.9	82.8
Valencia	Spain	35.4	68.5	60.3	68.6	74.8	79.1	79.7
Antwerp	Belgium	21.5	29	38	50.9	64.8	75	77.6
Bordeaux	France	32.3	34.4	43.4	31.3	42.4	67.5	76.1
Thessaloniki	Greece	1.2	3.1	14.3	43.8	42.8	68.8	73.9
Barcelona	Spain	30	61.3	71	74.3	73.9	73.4	73.1
Lisbon	Portugal	32.2	47.3	58	65.8	69.5	72.9	72
Piraeus	Greece	20.4	36.5	45.8	65.3	74.8	76.3	68.6
Genoa	Italy	36.5	46	45.2	49.7	65	61.7	63
Bilbao	Spain	26.4	33	53.1	46.7	49.2	58.1	58.9
Marseilles	France	32.3	42.4	50.5	46.9	53.2	54.2	56.9
Zeebrugge	Belgium	30.6	22.5	23.3	30	41.5	51	55
Rouen	France	23.1	40.4	36.7	31.8	32.9	36.5	42
Amsterdam	the Netherlands	21	21.6	30.2	40.5	25.9	22.9	29.7
Trieste	Italy	34.4	46.7	55.4	28.9	27.4	18.8	29.6
Dunkirk	France	14.6	14.7	10.5	11.5	27.9	13.9	15
Zeeland Seaports	The Netherlands	11.1	10	4.4	3.1	2.3	4.3	4.3

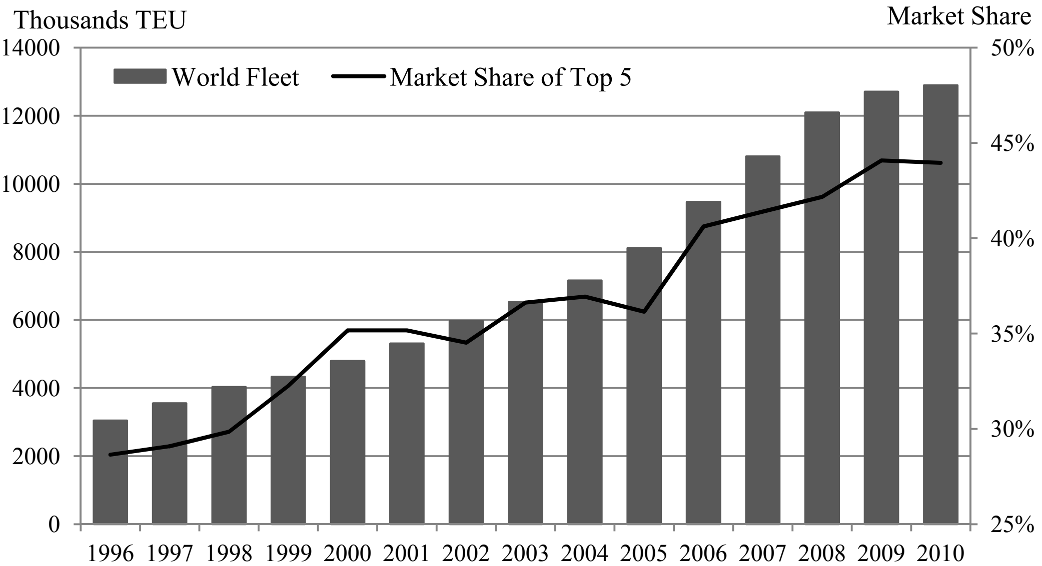
Source: Notteboom and Rodrigue (2008).

1.2 Concentration in the container market

Along with the market development, an increasingly fewer number of liner shipping companies are controlling the increasingly higher percentage of the world container carrying capacity. At the end of 1996, the world's 5 largest container shipping operators controlled 29% of the world container carrying capacity. By 2010, this number had increased to around 45% (AXSMarine, 2010) (Figure 1-2). This continued concentration in liner shipping raises new concerns over possible inefficiencies in the shipping market, especially after the abolishment of the anti-monopoly immunity of liner conferences. While the objective of limiting liner conferences is to increase the level of competition, this may in turn lead to a heightened level of concentration, because without the price cushion from conferences large and cost-efficient carriers may drive smaller players out of the market more easily (Fusillo, 2009).

It is worth pointing out that both concentration, which is defined as accumulation by individual producers, and centralization, which represents a merger of the capital employed by different companies, are defined as "economic concentration" or simply "concentration" (Chrzanowki, 1974; Chrzanowki, 1975). In this research, the term "concentration" is used to stand for "market concentration", where the capacity of a company is increased both through own capacity investment, and centralization through merger and acquisitions.

Figure 1-2: Evolution of world fleet and the top 5 operators' market share



Market concentration is not an issue unique to liner shipping. It has been a lasting hot topic in industrial economics (Curry & George, 1983; Davies & Geroski, 1997; Dufwenberg & Gneezy, 2000), mainly due to the undesirable social consequences associated with monopolies and a monopolistic market, such as excessive profit margins, inefficient production, price discrimination, insufficient quantity supplied, and shrinking social welfare. In the liner shipping industry, there are additional concerns over such continuing concentration. First of all, the process of market concentration, rather than the concentration itself, leads to possible excessive supply in the liner shipping industry. Shipping companies, especially the larger ones, are keen to retain their relative market share in the competitive market, even when the market is low. A typical example is Maersk line's recent huge new orders of 10 EEE[1] class container ships of 18,000 TEUs each, with an option to buy another 20, as a result of the fast capacity expansion of MSC (Mediterranean Shipping Company) in recent years (Alphaliner, 2011). This new order adds considerable capacity to the world fleet when the world's economic situation still being uncertain, the freight rate just recovering from its record-low trough, and the number of layups in the market still being high. Furthermore, smaller liners may find it difficult to survive in the market, let alone maintain their market shares. Secondly, the continued concentration of liner shipping has extended its impact on port terminal development (Heaver, 2000; Notteboom, 2002; De Souza et al., 2003; Midoro et al., 2005; Parola & Musso, 2007). The increasing bargaining power of major

[1] EEE stands for Energy efficiency, Environmental performance and Economies of scale, a name Maersk given to its latest generation container vessels.

liner shipping companies and the increased vessel size heightened the level of competition among nearby ports for the hub-port position of the liner shipping company. This leads to over-capacity in the container terminal facility. At present, many coastal municipalities and provinces have invested in huge container terminals so as to compete for the hub port-position in their region.

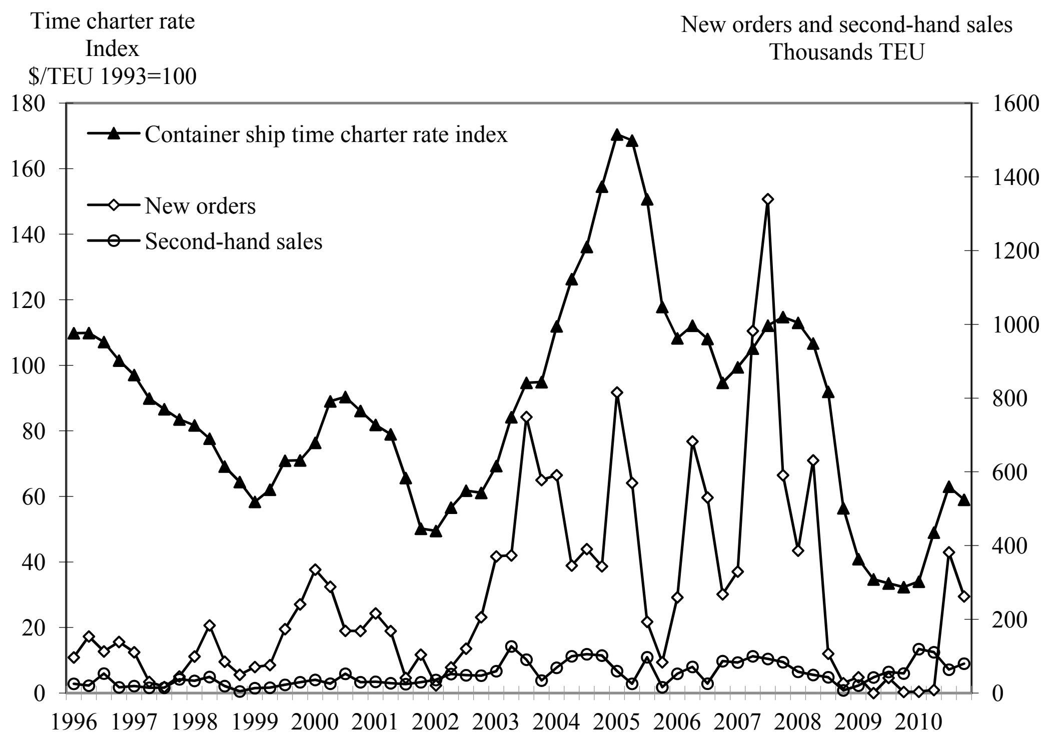
Based on the above analysis, in order to understand the formation of the increasing market concentration, and help policy makers to formulate various effective policies to deal with the issue of concentration, it is necessary to study the capacity expansion of individual companies and their investment behavior.

1.3 Cyclical nature of container shipping industry

1.3.1 Shipping freight cycles

Shipping is a capital intensive industry. In order to stay in the business, investors have to speculate on the future payoffs of the huge amount of capital investment cost. This collective speculation, along with the uncertain market demands and the construction lags of new orders make the container freight market volatile. Figure 1-3 displays the container ship time charter rate and world total container capacity orders (in thousand TEU slots) from 1996 to 2009. When the freight rate (as represented by the time charter index) is increasing, the expected high profitability in container shipping services motivates shipping companies to order new vessels so as to attract customers with better services and to gain a larger share in the global competitive market. When the capacity increase cannot keep pace with the demand, the market freight rate fluctuates.

Figure 1-3: Container time charter index and orders



Source: Clarkson Research Services Limited (2010)

Usually there are four stages in a shipping cycle. A market trough is followed by a recovery, leading to a market peak, followed by a collapse. After an overview the shipping cycles for the past 266-year period, Stopford (2009, p.131) concluded that each cycle is different in length, which makes it difficult to predict the next cycle. He analyzed that one reason the cycles are so unpredictable is that the investors themselves can influence the movement of the cycle. The cycles are described as a mechanism devoted to removing imbalances in the supply and demand. If there is too little supply, freight rates increase until more ships are ordered. If there are too many ships, freight rates decrease until the owners scrap some of the oldest ships. If the owners expect an upturn and decide not to scrap their ships, the cycle just lasts longer.

1.3.2 Impact of the freight cycles

The fluctuating container freight rate, as shown by the container time charter rate over the past two decades (Figure 1-3), has unhinged the profitability of the container shipping industry. When the freight rate is high, the high demand for container shipping services hastens shipping companies to order bigger and more efficient container vessels so as to attract global customers with better services at lower cost, and to gain a larger share of the global competitive shipping market. Companies with the most up-to-date container vessels can therefore out-perform others because of faster and more reliable services at a lower unit cost. While this reduction of sea transportation cost can induce additional demand, it also causes major problems for the companies with less efficient fleets. The usual practice of ‘passing the rent to shippers’ can decrease the freight rate, dissipate rent, diminish profit at the industry level, and even make some companies bankrupt. According to Drewry Shipping Consultants Ltd, in comparison with 2006, global carriers moved 14.7% more cargo, but earned 1.2% less revenue in 2008. On the main east-west trade routes, aggregated losses of the carriers amounted to \$2.4 billion, an 8% net loss. Maersk Line, the world’s largest shipping line, with more than 16% of the world’s liner fleet, suffered a \$568 million loss in 2006.

The low freight rate in the shipping cycle not only has a significant negative impact on business operations and investment decisions, but also causes extensive concerns at both national and international levels. Bankers, who finance the building or purchasing of ships, bear high financial risks due to the insolvency of shipowners when the freight rate is low. According to Volk (1984), most of the ship investment activities are concurrent with a high freight rate. Goulielmos and Psifia (2006) pointed out that bankers finance 75-80% of ship construction costs. Therefore, it is essential for the bankers to understand the shipping cycle and take it into consideration when making loan decisions.

Low freight rates and thin profits in the shipping industry can also create extensive concerns over maritime policy and administration. 'Safer Shipping and Cleaner Oceans', once the mission statement of the International Maritime Organization, resonates the wide concerns over substandard vessels and crews, two of the critical factors in maritime accidents that have caused loss of life and property at sea, as well as marine environmental pollution. Although the main focus of this mission is to curb substandard ships in bulk and tanker market, the cost minimization behavior in liner shipping could also lead to the same problem if the standards in ships and crew are not maintained. These undesirable incidents most likely follow when shipowners have insufficient earnings to maintain their ships and train their crews. To stay in business when the freight rate is low, ship operators have to reduce operational costs in vessel maintenance and manning, even replacing qualified crews with inexperienced, low salary ones. This can increase the number of substandard vessels, impair maritime safety, heighten maritime casualties, and undermine sustainability in maritime shipping.

According to a report prepared by SSY Consultancy & Research Ltd for OECD Maritime Transportation Committee (2001), low freight rates in the previous 30 years was the most important factor in substandard shipping, which caused huge economic losses.

From the perspective of national and regional public policy, perhaps the major concern is the mass layoffs in the shipping industry during low freight rate periods. When the freight revenue cannot cover its operating costs, a shipping company has to lay up a ship and lay off its employees. This is particularly harmful to those developing countries supplying a large maritime work force or providing various kinds of services to the shipping industry. The massive layoffs in the shipping industry when facing a low freight rate can significantly increase the unemployment rate in those countries. On January 9, 2008, having suffered huge losses in 2006 and a very low profit in 2007, Maersk Line announced in the Los Angeles Times that it planned to lay off as many as 3,000 people from the 25,000 employees in its container division. On November 6, 2008, as part of its global layoff plan, Maersk A/S announced that it would cut 700 positions in the Chinese market by 2009, and shut down the global services centre in Guangzhou. This province had already suffered massive layoffs recently resulting from the shutting down of many manufacturers facing weak export demand. Additional layoffs from the shipping company would further exacerbate the economic situation in this region.

Motivated by the cyclical nature of the shipping industry and its huge impact on both the private and public sectors, this thesis endeavors to investigate the fluctuation of the container shipping market and the market adjustment principles using dynamic market analysis.

1.4 Research problems

Previous sections discussed the capacity development of the container liner market (Section 1.1), the increasing market concentration (Section 1.2), and the cyclical nature of the freight rate (Section 1.3). However, a search through relevant literature shows that, despite the significant contribution of container shipping to the world seaborne trade, studies on economic modeling and statistical analysis of the container shipping market is scarce, especially with regard to capacity expansion and investment. Therefore the following four research questions are successively developed.

The first research question concerns fluctuations in the container shipping market. The shipping market is characterized by fluctuations in which the ups and downs of the freight rate are determined by the alternating over-capacity in shipping supply in one period, followed by excessive demand for freight transportation services in another. Stopford (2009) stated that the fluctuation is caused by the investment behavior of shipowners and the lag between new orders and the subsequent increase in shipping capacity.

The fluctuation of the freight rate is harmful to both the private and public sectors, as analyzed in the Section 1.3, and this has, therefore, prompted numerous efforts to be made to understand, describe, model and predict the fluctuation of the shipping freight rate. However, most of the prior research focuses on modeling the freight rate directly in a stochastic model (Hsu & Goodwin, 1995; Kavussanos, 1996; Veenstra, 1999; Kavussanos, 2003; Tsolakis et al., 2003; Haigh et al., 2004; Haralambides et al., 2005; Glen, 2006; Lu et al., 2008; Merikas et al., 2008). Few studies have concentrated on the underlying mechanism of the market and on how the shipowner and the market adjust the fleet capacity investment and freight rate based on the economic environment at the time. From the economics point of view, shipowners order new ships if they observe positive profit, and retire old ships if the profit is negative. When the freight rate is at a high level, shipowners use the profit gained to invest in new capacities. However, as there are lags in the construction of ships, when the ships finally come to the market there is more supply than needed. This pushes the freight rate down. Profit goes down due to a low freight rate level. Shipowners begin to demolish some aged ships that need more maintenance and bunker, supply begins to decrease, and freight rates gradually rise. Therefore, based on the above description the first research question raised in this thesis is:

Research Question 1: *what are the market movement and adjustment principles in the container liner market?*

Following on from Research Question 1 about the fluctuations of market capacity and freight, the thesis moves on to looking at the factors influencing individual liner companies' capacity expansion, because individual expansion has caused a high concentration in the container market, as introduced in Section 1.2.

Actually, the importance of market concentration has promoted extensive studies in this field. Many have studied market contestability in liner shipping, as well as the effectiveness of the regulations on market structure (Davies, 1986; Pearson, 1987; Franck, 1991; Pons, 2000; Benacchio et al., 2007). Others have analyzed Mergers and Acquisitions (M&A) and strategic alliances in the liner shipping industry (Heaver, 2000; Midoro & Pitto, 2000; Notteboom, 2002; De Souza et al., 2003; Fusillo, 2009). ECLAC (1998) investigated the concentration in the liner shipping market. He analyzed the causes of M&A from the three different aspects of economic background, government regulation and technology. He also summarized the impacts of market concentration on cost, profit, market over-capacity, freight fluctuation and so on. Sys (2009) examined the market structure of the containerized liner shipping industry. He argued that the liner market is characterized by increased concentration due to M&A, but that it is still a fragmented or contestable industry. In general, the container shipping industry is an oligopolistic market, with some trade lanes characterized as a loose oligopoly and others as a tight oligopoly.

Although there are extensive literatures on various aspects of market concentration, there are no existing researches explaining the variations in the capacity growth rates among different liner shipping companies – a fundamental element determining the concentration in liner shipping. For liner shipping companies, the growth of controlled capacity comes from two pathways. First, they purchase more ships, or charter from other companies, in order to meet the increased demand, to replace the old inefficient fleet, or to keep their market share in the competitive market. This is the most common pathway for capacity growth which is the accumulation of capacity by individual producers. The second less common pathway is the capacity growth through M&A (Reitzes, 1993; ECLAC, 1998; Heaver, 2000; Pons, 2000; Notteboom, 2002; De Souza et al., 2003; Benacchio et al., 2007), which is also called centralization by merging of the capacity employed by different companies. Although the number of M&A is not large, each event could have a significant impact on the growth of controlled capacity for the surviving liner company as a result of the M&A. On the other hand, liner conferences/alliances are just the cooperation agreements among the liners for resource sharing (Midoro & Pitto, 2000). Their impact on the structure of the shipping market are not sufficient to reduce the competitiveness of the market (Pons, 2000), as they are unlikely to result in sustained high profit margins in the dynamically competitive shipping industry (Heaver, 2000; Pons, 2000).

As industrial capacity and its concentration are determined collectively by the expansion behavior of individual shipping companies (Stopford, 2009), analyzing individual behavior in capacity expansion, especially of the large companies, is essential to understanding the economic factors that drive the industrial capacity changes and market concentration in the container liner market. Thus, the second research question is intrigued:

Research Question 2: *How do the container liner companies individually make their capacity expansion?*

The third and fourth questions are concerned with the ship investment when liner companies are expanding their ship capacity.

As introduced above, the two most common ways of expanding capacity are purchasing or chartering vessels. Whether to purchase a ship and which type of ship to purchase are two important ship investment decisions that not only affect the profitability of liner shipping companies, but also the development of the shipping industry and the world economy. Modern shipping industries are capital-intensive, especially in liner shipping. According to Drewry (2010), a super post-Panamax vessel capable of carrying 12,000 TEUs costs about US$113.5 million. In addition, the capital cost accounts for approximately half the total cost of running a large new ship (Gentle & Perkins, 1982; NordBank, 2008; Stopford, 2009). Therefore, liner shipping companies have to be extremely careful when making ship investment decisions. Under-investment would result in a loss of earnings and diminishing market shares, and would endanger the long-term competitive position of a shipping company, whilst over-investment can cause negative cash flow due to the high financial cost, especially when the freight rate is low. At the industry level, inappropriate investment decisions by individual shipping companies can give rise to market imbalance and a volatile freight rate. This not only impairs the performance and welfare of the shipping industry, but also of multinational businesses that rely on global carriers for their worldwide logistics operations. It can even have significant impact on the world economy, especially during difficult times. For example, massive investment before financial crisis in 2008 created huge over-capacity, which led to the record low freight rate in September 2009 and made it difficult for shipping companies to keep their ships active, resulting in huge demolitions of container ships. According to statistics from Alphaliner (2010), 364 thousand TEUs were scrapped in 2009, up from 100 thousand in 2008, and less than 2 thousand in 2005. This huge demolition and layup not only caused economic losses in the shipping industry, but also made global carriers increase user charges in order to keep themselves in business. In consequence, this added to the difficulties of economic recovery, as manufacturers who were already struggling in the slow economy had to pay more for the shipping costs.

In addition to purchasing their own ship, liner shipping companies have many channels to increase their capacity. In the conference environment, they may practice slot chartering or slot sharing and use the capacity of others to increase their flexibility. To meet temporary needs in an uncertain market, liners may time charter short-term capacity. They can also charter bareboats to increase their long-term capacity, in order to reduce the financial risks associated with high fixed assets and to increase capital returns (Gorton et al., 1999; Williams, 1999). Comparing all such possible channels, the ship purchasing decision has the most direct and significant long-term impact on the business performance of a shipping company. It not only affects the financial status of the shipping company, but also its attractiveness and the confidence of its investors and stakeholders. In addition, because liner shipping companies are the experts in shipping, their investment decision is also a 'thermometer' for the shipping market. Potential and existing charter owners who have no experience in shipping tend to follow the liners in their ship investment decisions. Studies of the ship investment behavior of liner shipping companies can, therefore, support decision makers in shipping companies, as well as the investors and financial institutions in the shipping sector.

In addition to the decision on whether to buy a ship, the selection of a specific ship type also has a significant impact on liner performance. In some situations second-hand ships may be a better choice, due to lower capital requirements and the absence of lead-time. Once purchased, it can earn immediate profit (Haralambides et al., 2005; Merikas et al., 2008). However, the drawbacks of second-hand ships, such as higher operational costs, lower performance, and shorter trading lives, may reduce the competitiveness of a shipping company. For long-term planning, therefore, ordering new ships is a better decision, because it can adopt the most up-to-date technologies in shipbuilding, and further explore cost savings in economies of scale. In practice, some shipping companies also speculate by buying when the freight rate is low and selling when it is high. However, the statistics show that the number of transactions that belong to this category is low, due to the uncertainties in the future market and high financial risk. Therefore, they are not considered in this research.

The difficulties involved in making ship investment decisions and the significant role that ship investment plays in both the private shipping business and in international trade, as stated above, highlight the importance of studying ship investment behavior. Therefore, research questions 3 and 4 are proposed as follows:

Research Question 3: *How do container liner companies make their ship investment decisions?*

Research Question 4: *How do container liner companies choose which vessel to invest among the different types of vessels?*

1.5 Research objectives

The research wishes to make a contribution towards predicting market movements, and to highlight the underlying factors driving an individual liner company's capacity expansion and investment decisions. The objective of this research involves the following three perspectives:

Firstly, this thesis endeavors to build a dynamic-economic model for the container shipping market, and to test it using annual data from past observations. Furthermore, it tries to reveal the significance of collective market adjustment principles using the observed data, but without involving complexities in individual behavior analysis, such as market competition strategies, speculation, and hedging.

Secondly, this thesis addresses the problem of market concentration, which is caused by companies' capacity expansion, by studying the growth rate of the liner companies. It tries to help policy makers in formulating various effective policies to deal with this concentration issue. The motivations for capacity expansion include not only the operational needs for meeting market demand, but also strategic measures to maintain the market position in the competitive environment. Different responses of capacity expansion to the market conditions and other companies' expansion will be tested for the shipping companies.

Finally, the questions of when to purchase their own ships and how to select ships are two critical decisions for the development and operation of the container liner company. These are difficult issues to address because of the complexity of the shipping industry, so in order to address these issues this thesis attempts to explore important factors in ship investment by analysing the actual ship purchasing decisions and ship choice records of the liner companies in the world.

1.6 Structure of thesis

The organization of this thesis is summarized in Figure 1-4.

Figure 1-4: Thesis structure and research flow

Chapter 1 introduces the background information, which includes the development of the container market and the two major issues of market concentration and the cyclical nature of the freight rate. Then it presents the research problems and research objectives.

Chapter 2 reviews existing studies relevant to container shipping market modeling, market evolution, capacity expansion and investment. Chapters 1 and 2 help to identify the research questions in this thesis using qualitative analysis.

Chapter 3 discusses the methodology used in solving the research questions in the succeeding four chapters, including system equations, different types of logit models, and panel data methods. It also presents the data sources used in this research.

In chapters 4 to 7, the four research issues corresponding to the research questions are analyzed respectively. Chapter 4 studies the fluctuations of the market fleet capacity and freight rate using theoretical and econometric models and empirical data; chapter 5 analyzes the individual container liner companies' capacity expansion behaviors; chapter 6 investigates the liner companies' ship investment decisions; and chapter 7 considers the liner companies' specific choices of different types of ship.

The last chapter, chapter 8, summarizes the main findings of the thesis, discusses the academic and policy implications together with the thesis limitations, and then proposes recommendations for future research.

Chapter 2: Literature review

This chapter presents critical reviews of the literature relevant to shipping market modeling, capacity development and capacity investment.

2.1 Shipping market modeling

Due to the importance of the cyclical nature of the container shipping market, as described in the introduction, many researchers have studied the shipping market in order to have a clear understanding of the market movement. The modeling in the bulk and tanker shipping markets has been studied by many researchers. Broadly speaking, two schools of thought have developed. Firstly, many researchers have focused on modeling the supply and demand for transportation using a structural model (Norman & Wergeland, 1981; Beenstock & Vergottis, 1989a; 1993; Evans, 1994). Secondly, in recent years, inspired by developments in financial economics, the focus has been on modeling the freight rate directly in a reduced form model (Kavussanos, 1996; Kavussanos, 1997; Kavussanos & Alizadeh, 2002).

2.1.1 Structural models on the shipping market

Starting with Koopmans (1939), there are some studies that have discussed the appropriate specification of supply and demand in traditional shipping markets (Tinbergen, 1959; Hawdon, 1978; Charemza & Gronicki, 1981; Beenstock & Vergottis, 1989a; 1989b; 1993; Tvedt, 2003).

Koopmans (1939) examined the behavior of tanker freight rates assuming market equilibrium between supply and demand. He found that, in the short run, the only possibility of increasing supply when all the vessels in a fleet are already employed is through higher utilization of the existing ships. This can be achieved by higher vessel speed, reduced port time, shorter ballast legs, and delaying regular maintenance. However, this method of increasing the supply is limited by technical constraints and the higher marginal cost of operation due to higher fuel consumption. When all the ships are sailing at high speed with a full cargo load, the supply function becomes almost vertical, and therefore totally inelastic. When there is excessive supply, the freight rate is very low. In this case, the supply function is almost horizontal, making it extremely elastic to the changes in freight rate. When demand meets supply, there would be a different impact on rates depending on whether the region is elastic or inelastic. Koopmans (1939) explained the high volatility of tanker freight rates at periods of prosperity around a very high level, and the stability of tanker freight rates at periods of depression around a low level. However, Koopmans only investigated the sensitivity of freight rates at different situations of supply. He did not examine the impact of freight rates on market capacity, since freight rate and capacity are mutually influenced in the shipping market.

Tinbergen (1959) investigated the sensitivity of freight rates to changes in the level of demand and the factors affecting supply. The author considered demand to be perfectly inelastic with respect to freight rates. Supply responds positively to freight rates and shifts with changes in the size of the fleet or the price of fuel. Assuming that freight rate clears each year, the equilibrium freight rate can be written as a function of demand, fleet, and the price of fuel. He also developed a theoretical model to analyze the evolution of the fleet using dynamic relationships between shipbuilding, freight rates and the fleet. He concluded that a low fleet leads to high freight rates and large orders for ships. Orders placed during a prosperous market period would be delivered about one year later, thus increasing the total fleet. Hawdon (1978) developed a model that determines tanker freight rates both in the short-term and long-term. In the short-term the fleet is fixed and freight rates are determined by the prevailing level of demand, fleet and fuel prices. In order to explain the dynamic evolution of rates over long-term periods, Hawdon (1978) explicitly considered both shipbuilding and the scrapping market. He estimated his model using data between 1950 and 1970. This model was then used for simulating the long run development of the market under various assumptions.

However, Tinbergen and Hawdon's work did not include an explicit supply and demand framework, where the determinants for demand and supply are separated.

Beenstock and Vergottis (1993) summarized their research on econometric modeling on world shipping in the book *Econometric Modeling of World Shipping*, which significantly contributed to the empirical analysis of the shipping market. Their study is the most fully specified structural econometric model of both the tanker and dry cargo freight markets (Glen, 2006). Beenstock and Vergottis (1989a; 1989b; 1993) described a theoretical model in which freight markets and ship markets are interdependent and in which second-hand ships are treated as capital assets. BV's models of dry cargo and tankers have common characteristics. The freight rate is determined by the proportional difference between quantity demanded (in tonne miles) and the supply of ship services (measured by the fleet tonnage). Demand is exogenous, and freight rate is a function of the balance between the exogenous demand and the active fleet. The active fleet is a function of freight rates, bunker prices, and operating and layup cost. In 1989, Beenstock and Vergottis applied this theoretical model in the dry cargo and tanker markets. They estimated the aggregate econometric models simultaneously, in which freight rates, layups, new and second-hand prices and the size of the fleet are jointly and dynamically determined. The model provides a good statistical account for the markets since 1960 and tracks the data quite accurately.

Tvedt (2003) used structural and econometric stochastic methods together, and developed a continuous-time stochastic partial equilibrium model of the freight and new building market. He found that the equilibrium freight rate process is close to that of a standard geometric mean reversion process. However, Tvedt's model is very theoretical and does not explicitly model the time-varying shape of the supply curve, or the scrapping and ordering behavior.

2.1.2 Reduced form models on shipping market

Inspired by developments in financial economics, atheoretical, time-series models have also been developed recently into the analysis of freight rates and ship prices (Kavussanos, 1996; 1997; Veenstra, 1999; Kavussanos & Nomikos, 2003; Tsolakis et al., 2003; Alizadeh & Nomikos, 2007; Lu et al., 2008; Merikas et al., 2008). As it is dealing with non-stationary time changing variables, the time series methods can be interpreted as attempts to evaluate variable relationships in a dynamic framework.

Since Engle and Granger (1987), Johansen (1988), and Johansen and Juselius (1990) developed the method of testing whether or not a long-run relationship exists between the variables, many researchers have used the cointegration method to test the existence of cointegration in the shipping market. Among them, Hsu and Goodwin (1995) and Kavussanos and Nomikos (2003) tested the existence of long-run relationships between freight rates and other variables, such as fuel price, new ship deliveries, and futures. Veenstra (1999) and Tsolakis et al. (2003) tested the various relationships of second-hand prices with time charter rates, new buildings and scrap prices. Alizadeh and Nomikos (2007) and Merikas et al. (2008) showed that the earning-price ratio and the ratio of newbuilding price to second-hand price can be used as an effective tool in investment decisions. Glen (1997) and Kavussanos and Alizadeh (2002) tested the validity of the Efficient Market Hypothesis (EMH) of ship prices in the dry bulk and tanker sectors.

In addition to cointegration analysis, some other researchers have been more interested in the analysis of volatility of freight rates and ship prices (Kavussanos, 1996; Kavussanos, 1997; Kavussanos, 2003; Lu et al., 2008) using the autoregressive conditional heteroskedasticity (ARCH) model or generalized autoregressive conditional heteroskedasticity (GARCH) model.

Generally speaking, the main trends in modeling the shipping market are as follows:

1. The main research area has been focused on the dry bulk and tanker markets. There have been few studies conducted on container market.
2. Statistical modeling rather than structural modeling. Since Beenstock and Vergottis there have been few studies that have applied structural modeling to the shipping market.
3. Greater focus on modeling rate variability than rate levels. These models are borrowed from finance, and have been applied in a very fruitful way using GARCH and EGARCH models for examining price dynamics in terms of the behavior of its volatility rather than its mean value.

Glen (2006) pointed out that more attention should be focused on the structural features of shipping markets, an element that has been downplayed following the adoption of 'rational expectations' modeling and the dominance of vector autoregressive models of dynamic behavior in these markets.

Reviewing the above reduced form models, suggests that, despite their success, time-series models have two major drawbacks: (1) Time-series models do not take into account prior structural knowledge of cause and causality effects, and (2) Time-series models do not easily support what-if scenarios and cannot take into account changes in exogenous variables or structure. Therefore, structural models are adopted in this analysis, since the underlying structures and factors are key issues in this thesis.

2.2 Capacity expansion and investment

As stated previously, the difficulties involved in ship investment and ship choice decision-making, together with the significant role that shipping capacity plays in both private shipping businesses and in international trade, highlight the importance of this study of behavior with regard to in ship investment.

2.2.1 Market structure and concentration

As shown in the introduction, in addition to the undesirable social consequences associated with concentration, there are new concerns over the process of market concentration in the container liner shipping industry, namely the over-supply caused by shipping companies' desire for market share and its impact on consolidation in the port terminals.

Actually, a lot of research has analyzed the market concentration in the container liner market caused by the expansion of individual companies. Among them, Davies (1986), Pearson (1987), Franck (1991), Pons (2000), Benacchio et al. (2007) investigated the contestability of the container liner market and the effectiveness of the regulations on market structure. Heaver (2000), Midoro and Pitto (2000), Notteboom (2002), De Souza et al. (2003), and Fusillo (2009) analyzed the horizontal and vertical integration strategies in the liner shipping industry through M&A or strategic alliances.

ECLAC (1998) investigated concentration in the liner shipping market. He analyzed the causes of M&A from the three different aspects of economic background, government regulations and technology. He also summarized the impact of market concentration on costs, profits, market over-capacity, and freight fluctuation and so on. After analyzing the causes and impacts of the process of concentration in the liner shipping industry, he finally concluded that no abuse of market power was detected. He pointed out that it would be a misconception of competition if the public sector tried to protect smaller players from its consequences, even if this results in a smaller number of larger market players.

Sys (2009) examined the market structure of the containerized liner shipping industry. He argued that the liner market is characterized by increased concentration due to M&A, but it is still a fragmented industry. In general, the container shipping industry is an oligopolistic market with some trade lanes characterized as a loose oligopoly, and others as a tight oligopoly.

Although the above literature focuses on various aspects of market concentration, none of them explained the fundamental element determining the concentration in liner shipping – the variation in the capacity growth rate among different liner shipping companies.

2.2.2 Capacity investment in ship market

On evaluating the large number of studies on market concentration, it is seen that there are relatively few publications analyzing ship investment decision making.

Jansson and Shneerson (1982) modeled the optimal ship size, in which they specified costs at sea and in port as a function of size. By minimizing costs per ton at sea plus costs per ton in ports, the model shows how optimal size varies as a result of changes in route characteristics (distance, handling rate, cargo balance) and factor prices (price of fuel).

Fusillo (2003) modeled the excess capacity and tested the assumption that excess capacity may be caused by the structural conditions of supply and demand, and that it may be deployed as a strategic defense against opportunistic rivals. Their empirical estimation finds limited support for the entry deterrence element of excess capacity in liner shipping.

Bendall and Stent (2005) assessed ship investment under uncertainty, using ROA (Real Option Analysis), in an express liner service. It demonstrated the use of ROA to value the flexibility available in management decision making.

Alizadeh and Nomikos (2007) proposed a cointegration approach for timing investment and divestment decisions in shipping markets. They showed that the relationship between price and earnings contains important information about the future behavior of ship price, which can be used for investment timing in shipping markets.

Merikas et al. (2008) introduced the relative price ratio of second-hand price over the newbuilding price as an effective tool in investment decisions when choosing between newbuildings and second-hand vessels. They found that in a booming freight market, a shipowner needs to buy a second-hand vessel, as it can be capitalized in the strong freight market. When the freight drops, the shipowner should order new vessels, due to the optimism regarding the recovery of the market in the future.

Wu (2009) developed an economic model to investigate the optimal fleet capacity of container shipping lines in Taiwan. His findings suggest that the strategy of holding excess capacity and maintaining market power may implicitly play a crucial role in determining the fleet capacity.

Although the above studies deal with the capacity management in the shipping market, none of them has investigated the capacity expansion, investment and selection behavior for liner shipping companies. However, the capacity expansion of and individual company is the fundamental element in determining the growth of market supply, which in itself is also an important element in market concentration. In addition, when to purchase their own ships and how to select a ship are both critical decisions affecting the development and operation of a company, yet they are difficult issues to address in view of the complexity of the shipping industry. As a first step in addressing these issues, this thesis attempts to explore the important factors in capacity expansion and ship investment, by analysing the actual expansion and investment records of the top 100 liners in the world.

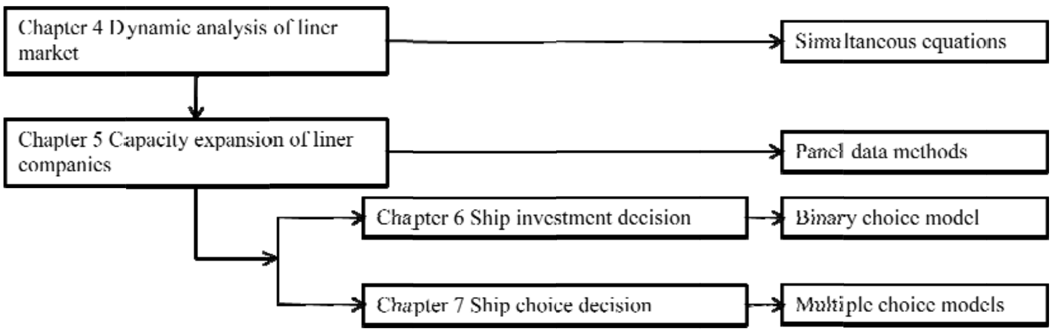
2.3 Summary

Despite the existing literature on shipping market analysis, there has been little empirical research on dynamic market analysis, ship capacity expansion or investment and ship selection behavior in the liner shipping market. Therefore, this thesis endeavors to reveal the important market adjustment principles, together with the factors that determine the liner companies' capacity expansion, investment decisions and ship type selections, using observed data from the container shipping market. The statistical and econometric methods used in this thesis include simultaneous equations, panel data methods and discrete choice models, all of which will be described in detail in the next chapter.

Chapter 3: Research methodology and data sources

The research problems defined in this thesis are investigated by using the following research process, as shown in Figure 3-1. On the basis of the objectives described in the introduction, dynamic market analysis, including movements of the market fleet and the freight rate, will be investigated first using system method of simultaneous equations. Then the capacity expansion strategies for each company will be analyzed using panel data methods. After that, each container liner company's investment decision is analyzed using a binary choice model. Next follows the ship choice decisions among different types of ships, which will be analyzed using multiple choice models.

Figure 3-1: Research flow and research methodology



The purpose of this chapter is to provide background information on the statistical models that will be applied in this thesis. Most of them are taken directly from existing literature. It is provided to make it easier for readers to understand the theoretical foundation of these statistical models.

3.1 Simultaneous equations

In the dynamic analysis of the container liner market, the movements of the market fleet and freight rate are modeled in two equations simultaneously, which can simulate the dynamic interaction between them. This type of equations is structural equation in that they are derived from theory and each describes a particular aspect of the economy (Greene, 2003). All the equations in the model are determined simultaneously, so the system is interdependent.

In the simultaneous equations, the variables determined by the system are called endogenous variables, and those determined by outside factors are called exogenous variables. It is noted that lagged endogenous variables are predetermined variables which can be treated as if they were exogenous in the sense that consistent estimates can be obtained when they appear as regressors.

If the solution for endogenous variables in terms of exogenous variables can be calculated, the system is said to be a complete system of equations. Judge et al. (1988) and Greene (2003) specified that the system is complete if the number of equations equals the number of endogenous variables.

3.1.1 Model identification

The reduced form of a system of equations is the result of solving the system for the endogenous variables. This gives the latter as a function of the exogenous variables. In a system, there is a certain amount of information upon which any inference about its underlying structure can be based. The structure is said to be unidentified if more than one theory is consistent with the same data, because there is no way of distinguishing them. The identification problem is a problem which can occur when the structural model is trying to be estimated from the reduced form. Greene (2003) stated that the order condition for identification of equations is that the number of exogenous variables excluded from any equation must be at least as large as the number of endogenous variables included in that equation.

3.1.2 Methods of estimation

In the simultaneous equations, the endogenous variables in one equation usually affect other variables in another equation. So the error terms are correlated with endogenous variables. For all T observations, the terms in the jth equation are

$$\begin{aligned} y_j &= Y_j\gamma_j + X_j\beta_j + \varepsilon_j \\ &= Z_j\delta_j + \varepsilon_j \end{aligned} \quad . \tag{3-1}$$

The M reduced-form equations are $Y = X\Pi + V$. Y is the vector of endogenous variables. X is the vector of exogenous variables. For the included endogenous variables $Y_j = X\Pi_j + V_j$. The least squares estimator is

$$d_j = [Z_j'Z_j]^{-1}Z_j'y_j = \delta_j + \begin{bmatrix} Y_j'Y_j & Y_j'X_j \\ X_j'Y_j & X_j'X_j \end{bmatrix}^{-1} \begin{bmatrix} Y_j'\varepsilon_j \\ X_j'\varepsilon_j \end{bmatrix} . \tag{3-2}$$

In Equation 3-2, $p\lim(1/T)X_j'\varepsilon_j = 0$, but $p\lim(1/T)Y_j'\varepsilon_j \neq 0$. This means that d_j are inconsistent, which is the 'simultaneous equations bias' of least squares (Greene, 2003).

Returning to the structural form, the OLS estimator of δ_j is inconsistent because of the correlation between Z_j and ε_j. A general method of obtaining consistent estimates is the method of using instrumental variables (IV). The exogenous and predetermined variables in the system are perfect instrumental variables for the estimation, because they are correlated with the endogenous variables as they appear in the equations, and they are independent to the error term as they are exogenous variables. Let W_j be a matrix that satisfies the requirement for IV estimator,

$$p\lim(1/T)W_j'Z_j = \Sigma_{wz} = a \text{ finite nonsingular matrix,}$$

$$p\lim(1/T)W_j'\varepsilon_j = 0,$$

$$p\lim(1/T)W_j'W_j = \Sigma_{ww} = a \text{ positive definite matrix.}$$

Then the estimated result of $\hat{\delta}_{j,IV} = [W_j'Z_j]^{-1}W_j'y_j$ are consistent and have asymptotic covariance matrix

$$\begin{aligned} Asy.Var[\hat{\delta}_{j,IV}] &= \frac{\sigma_{jj}}{T} p\lim[\frac{1}{T}W_j'Z_j]^{-1}[\frac{1}{T}W_j'W_j][\frac{1}{T}Z_jW_j]^{-1} \\ &= \frac{\sigma_{jj}}{T}[\Sigma_{wz}^{-1}\Sigma_{ww}\Sigma_{zw}^{-1}]] \end{aligned} \quad . \qquad (3\text{-}3)$$

There are two approaches for the estimation of simultaneous equations model, both based on the principle of instrumental variables. One is limited information estimator, which estimates the structural parameters of each equation separately using all the information of the exogenous and predetermined variables in the whole system. The ordinary least squares estimator, instrumental variable (IV) estimator, two-stage least squares (2SLS) estimator and limited information maximum likelihood (LIML) estimator all belong to this kind of estimator. However, this type of estimator ignores information concerning that endogenous variables may appear in other equations. It also ignores information that the error terms among the equations are correlated. Another type of estimation is the full information estimator or system methods of estimation. This kind of estimator jointly estimates the equations in the model and obtains a more efficient estimation. System methods include the three-stage least squares (3SLS) estimator and full-information maximum likelihood (FIML) estimator.

3.1.2.1 2SLS estimator

The method of 2SLS is the most common method used for estimating simultaneous equations models. The procedures in the 2SLS are as follows:

Stage1: Obtain the least squares predictions using regression of Y_j on X,

$$\hat{Y}_j = X[(X'X)^{-1}X'Y_j] = XP_j \, . \tag{3-4}$$

It can be shown that this produces the most efficient IV estimator absent of heteroscedasticity or autocorrelation (Greene, 2003).

Stage 2: Estimate δ_j using least squares regression of y_j on $\hat{Y}_j$ and X_j,

$$\hat{\delta}_{j,2SLS} = \begin{bmatrix} \hat{Y}_j'\hat{Y}_j & \hat{Y}_j'X_j \\ X_j'\hat{Y}_j & X_j'X_j \end{bmatrix}^{-1} \begin{bmatrix} \hat{Y}_j'y_j \\ X_j'y_j \end{bmatrix}. \tag{3-5}$$

The estimated asymptotic covariance matrix of the coefficients are

$$Est.Asy.Var[\hat{\delta}_{j,2SLS}] = \hat{\sigma}_{jj}[\hat{Z}_j'\hat{Z}_j]^{-1} . \tag{3-6}$$

Where $\hat{\delta}_{jj} = \dfrac{(y_j - Z_j\hat{\delta}_j)'(y_j - Z_j\hat{\delta}_j)}{T}$, using the original data.

3.1.2.2 3SLS estimator

In search of a more efficient estimator, the whole system of M structural equations can be written as

$$\begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_M \end{bmatrix} = \begin{Vmatrix} Z_1 & a & \cdots & 0 \\ 0 & Z_2 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & \cdots & Z_M \end{Vmatrix} \begin{bmatrix} \delta_1 \\ \delta_2 \\ \vdots \\ \delta_M \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_M \end{bmatrix}, \tag{3-7}$$

or $y = Z\delta + \varepsilon$, where $E[\varepsilon \mid X] = 0,$ and $E[\varepsilon\varepsilon' \mid X] = \overline{\Sigma} = \Sigma \otimes I$.

Consider the IV estimator formed as

$$\overline{W} = \hat{Z} = diag[X(X'X)^{-1}X'Z_1,\ldots,X(X'X)^{-1}X'Z_M] = \begin{bmatrix} \hat{Z}_1 & 0 & \cdots & 0 \\ 0 & \hat{Z}_2 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & \cdots & \hat{Z}_M \end{bmatrix}, \tag{3-8}$$

The 3SLS estimator can be calculated as follows:

Stage 1: Estimate $\prod$ by ordinary least squares and compute $\hat{Y}_j$.

Stage 2: Compute $\hat{\delta}_{j,2SLS}$ for each equation the same as in 2SLS; then

$$\hat{\sigma}_{ij} = \frac{(y_i - Z_i\hat{\delta}_i)'(y_j - Z_j\hat{\delta}_j)}{T}. \tag{3-9}$$

Stage 3: Compute the GLS estimator according to $\hat{\delta}_{j,3SLS} = [\hat{Z}'(\Sigma^{-1} \otimes I)\hat{Z}]^{-1}\hat{Z}'(\Sigma^{-1} \otimes I)y$, where Σ can be obtained from the 2SLS estimates. The estimate of the asymptotic covariance matrix is then $Asy.Var[\hat{\delta}_{j,3SLS}] = [\hat{Z}'(\Sigma^{-1} \otimes I)\hat{Z}]^{-1}$.

3.2 Logit models

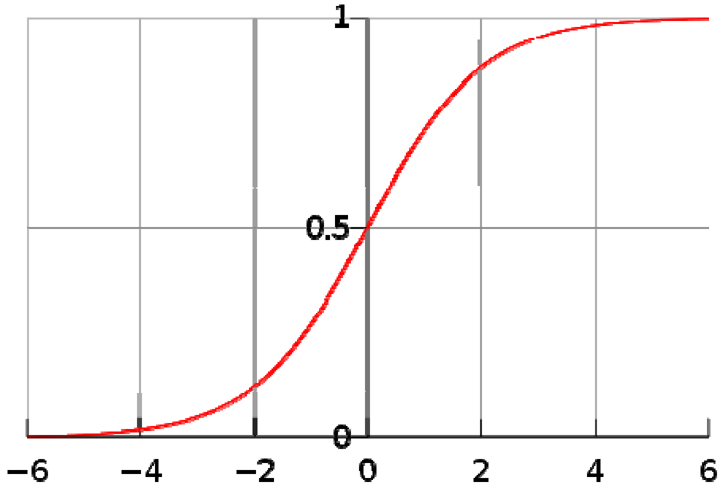
Choice-based samples are often used in transportation and individual behavior analysis to explain individuals' choices, using the attributes of each alternative, individual and the environment (Mcfadden, 1978; Mcfadden, 1980; Train, 2003). This section introduces discrete choice models, including binary and multiple logit models, which are applied in the analysis of ship investment decisions and ship choice decisions.

3.2.1 Logistic function

A logistic function or logistic curve is a common sigmoid curve (Figure 4-2) that is defined by the formula:

$$P(z) = \frac{e^z}{1+e^z} \tag{3-10}$$

Figure 3-2: Logistic curve



It is easy to calculate its derivatives:

$$\frac{d}{dz}P(z) = P(z)[1 - P(z)] \,, \tag{3-11}$$

and it also has the property of $1 - P(z) = p(-z)$. Because of its mathematical convenience, logistic distribution has been used in many applications (Greene, 2003). In statistics, logistic regression (or logit regression) is used for prediction of the probability of occurrence of an event by fitting data to a logistic curve. The logistic distribution is similar to the normal distribution except in the tails, which are considerably heavier. Therefore, the two distributions tend to give similar probabilities.

3.2.2 Binary logit model

3.2.2.1 Models for binary choice

Discrete dependent variable in the investment decision model is specified in the form of index function models, where it is assumed that there is some underlying (and unobserved) response variable $y \in (-\infty, +\infty)$. Although y cannot be observed directly, a binary outcome Y can be observed, such that:

$$Y = 1 \text{ invest}, \textit{if } y > 0,$$

$$Y = 0 \textit{ not } \text{invest}, \textit{if } y \leq 0 \quad (3\text{-}12)$$

The index function can be modeled as

$$y = x'\beta + \varepsilon \quad (3\text{-}13)$$

where ∂ represents an unobservable stochastic component. x is a set of explanatory variables that affect the investment decision making. β is a set of coefficients which is needed to be estimated. This model postulates that the probability that a liner company would invest is a function of observable factors and a random element resulting from non-observable factors. This now gives:

$$E(Y \mid x) = P(Y = 1 \mid x) = P(y > 0 \mid x) = P(\varepsilon > -x'\beta) = 1 - F(-x'\beta) = F(x'\beta) \,. \quad (3\text{-}14)$$

where $F(.)$ represents the cumulative distribution function (cdf) of ε. If F is the cdf of standard normal distribution, it is a probit model. If F is the cdf of logistic distribution, it is a logit model (Greene, 2003). In this thesis, the logit model for the parameter estimation is selected.

It is important to note that the estimated coefficients β are not the customary marginal effects like those of OLS linear regression models. In general,

$$\frac{\partial E[y \mid x]}{\partial x} = \left\{ \frac{dF(x'\beta)}{d(x'\beta)} \right\} \beta = f(x'\beta)\beta, \qquad (3\text{-}15)$$

where $f(.)$ is the density function that corresponds to the cumulative distribution, $F(.)$.

3.2.2.2 Estimation method

Estimation of binary choice models is usually based on the method of maximum likelihood estimation method (MLE) (Greene, 2003). Each observation is treated as a single independent draw from a Bernoulli distribution with success probability $F(x'\beta)$. The joint probability or likelihood function for a sample of n observations can be written as,

$$L(\beta|data) = \prod_{i=1}^{n} [F(x_i'\beta)]^{y_i} [1 - F(x_i'\beta)]^{1-y_i}. \qquad (3\text{-}16)$$

Taking logs,

$$lnL = \sum_{i=1}^{n} \{y_i lnF(x_i'\beta) + (1 - y_i) \ln [1 - F(x_i'\beta)]\}. \qquad (3\text{-}17)$$

Taking first derivatives on equation 3-17, the likelihood equations can be obtained,

$$\frac{\partial lnL}{\partial \beta} = \sum_{i=1}^{n} (y_i - \mathrm{A}_i)\, x_i = 0, \qquad (3\text{-}18)$$

where $\mathrm{A}_i = \frac{e^{x_i'\beta}}{1+e^{x_i'\beta}}$ is the logistic cumulative distribution function.

The negative definite of the second derivatives for the logit model ensures the existence of the maximum of the log-likelihood.

$$H = \frac{\partial^2 lnL}{\partial\beta\partial\beta'} = -\sum_i \wedge_i (1 - \wedge_i) x_i x_i'. \quad (3\text{-}19)$$

Finally, the iterative methods such as Newton, BHHH (Berndt, Hall, Hall, and Hausman estimator), or Newton-Raphson, can be used to obtain the successive approximations to the solution until the approximations converge to the correct value.

3.2.2.3 Goodness of fit

For single restriction, the simplest method would be based on the usual *t*-test using the standard errors from the information matrix. For the overall fitness of the model, there are many fitness measures suggested for discrete dependent models. The likelihood statistic lnL can be used to assess the fitness of the model. A Pseudo R^2 analog to that in a conventional regression used in this study is McFadden's (1974) likelihood ratio index,

$$Pseudo\ R^2 = LRI = 1 - \frac{lnL}{lnL_0}. \quad (3\text{-}20)$$

lnL_0 is the log-likelihood computed with a constant term only.

The overall significance of the beta's coefficients for the independent variables in the model can be tested by the likelihood ratio (*LR*) test, which is based on the null hypothesis that the beta's coefficients for the covariates in the model are equal to zero. The *LR* statistic takes the form:

$$LR = -2\ln\left(\frac{L_0}{L}\right). \quad (3\text{-}21)$$

The distribution of LR is a chi-square with q degree-of-freedom, where q is the number of covariates in the logistic regression equation.

3.2.3 Multiple choice models

In multiple choice models, there are usually two or more alternatives to choose from for one single decision. These polytomous response models can be classified into two distinct types, depending on whether the response variable is ordered or unordered.

In an ordered model, the response variable of an individual is restricted to one of several ordered values, for example, a bond rating is, by design, a ranking choice structure. In an unordered model, the multiple responses variable does not have an ordered structure, for example, travel mode and occupational choice. In this study, when the liner company is making their investment decision, the alternatives are the types or sizes of the ship, which is obviously an unordered choice model. As a result, the unordered multiple choice models of multinomial logit model (ML), conditional logit model (CL) and nested logit model (NL) will be considered in this section.

According to McFadden (1974) and Greene (2003), unordered choice models can be motivated by a random utility model. For the ith decision maker faced with J choices, suppose that the utility of choice j is

$$U_{ij} = z_{ij}'\beta + \varepsilon_{ij} \ . \tag{3-22}$$

If the decision maker chooses choice j in particular, then U_{ij} is assumed to be the maximum among J utilities (McFadden, 1974; Greene, 2003). Hence, the statistical model is

$$Prob\left(U_{ij} > U_{ik}\right) for\ all\ other\ k \neq j. \tag{3-23}$$

By assuming different distributions for the disturbances, the model can be estimated, for example, logit and probit. Used in this setting the probit model is rather limited because of the need to evaluate multiple integrals of the normal distribution. McFadden (1974) has shown that if (and only if) the J disturbances are independent and identically distributed (*i.i.d.*) with type I extreme value (Gumbel) distribution, $F(\varepsilon_{ij}) = \exp(-e^{-\varepsilon_{ij}})$, then $P(Y_i = j) = \dfrac{e^{z'_{ij}\beta}}{\sum_{j=1}^{J} e^{z'_{ij}\beta}}$.

3.2.3.1 Multinomial logit model

When the data contains only individual specific variables, the model can be estimated using a multinomial logit model, in which the choice is a function of the characteristics of the individual making the choice. For example, the occupation choice of menial, blue collar, craft, white collar, and professional with regressors of education, experience, race, and sex etc. The multinomial model for this occupational choice is

$$Prob(Y_i = j) = \frac{e^{\beta'_j x_i}}{\sum_{i=0}^{4} e^{\beta'_j x_i}}, j = 0,1,2,3,4. \tag{3-24}$$

3.2.3.2 *Conditional logit model*

When the data consists of choice-specific attributes instead of individual characteristic variables, the conditional logit model is appropriate, as a choice among alternatives is treated as a function of the characteristics of the alternatives,

$$Prob(Y_i = j | z_{i1}, z_{i2}, \dots, z_{iJ}) = \frac{e^{\beta' z_{ij}}}{\sum_{j=1}^{J} e^{\beta' z_{ij}}}. \quad (3\text{-}25)$$

Similar to the binary logit model, the coefficients are not the marginal effects. The marginal effects can be obtained by differentiating (4-25) with respect to *z*,

$$\frac{\partial P_j}{\partial z_k} = [P_j(1(j = k) - P_k)]\beta, k = 1, \dots J. \quad (3\text{-}26)$$

It is clear that every attribute set z_j would affect all the probabilities. For example, when the price of a Feeder ship increases, the probability of choosing a Feeder decreases, while the probabilities of choosing other types of ships, such as Handy, Panamax, Sub-Panamax, or Post-Panamax increase. It is also useful to calculate the elasticity of the probabilities of the effect of attribute *m* of choice *k* on P_j,

$$\frac{\partial log P_j}{\partial log z_{km}} = z_{km}[1(j = k) - P_k]\beta_m. \quad (3\text{-}27)$$

Newton's method, or the method of scoring, can be used to estimate the conditional logit model (Greene, 2003). Defining d_{ij}=1 if Y_i=j and 0 otherwise, the log-likelihood function is

$$logL = \sum_{i=1}^{n} \sum_{j=1}^{J} d_{ij} logProb(Y_i = j). \quad (3\text{-}28)$$

Then the gradient and Hessian can be calculated conveniently,

$$\frac{\partial \log L}{\partial \beta} = \sum_{i=1}^{n} \sum_{j=1}^{J} d_{ij} \left(z_{ij} - \sum_{j=1}^{J} P_{ij} z_{ij} \right), \quad (3\text{-}29)$$

$$\frac{\partial^2 \log L}{\partial \beta \partial \beta'} = -\sum_{i=1}^{n} \sum_{j=1}^{J} P_{ij} \left(z_{ij} - \sum_{j=1}^{J} P_{ij} z_{ij} \right) \left(z_{ij} - \sum_{j=1}^{J} P_{ij} z_{ij} \right)'. \quad (3\text{-}30)$$

3.2.3.3 *Tests for Independence from Irrelevant Alternatives* (*IIA*)

In the multinomial and conditional logit model, the disturbances are assumed independent and homoscedastic. This leads to the problematic aspect of the multinomial and conditional logit models, the odds ratios between any two alternatives are independent of the other alternatives, which is called independence from irrelevant alternatives (IIA),

$$\frac{P_{ij}}{P_{ik}} = \frac{e^{z'_{ij}\beta} / \sum_{l=1}^{J} e^{z'_{il}\beta}}{e^{z'_{ik}\beta} / \sum_{l=1}^{J} e^{z'_{il}\beta}} = e^{(z'_{ij} - z'_{ik})\beta} . \quad (3\text{-}31)$$

It is evident that the ratio of the probabilities for alternatives *j* and *k* does not depend on any alternatives other than *j* and *k*. However, the IIA property is restrictive from the point of view of choice behavior. The change in the attributes of one alternative changes the probabilities of the other alternatives proportionately, such that the ratios of probabilities remain constant. Thus, cross elasticity due to a change in the attributes of an alternative *j* are equal for all alternatives $k \neq j$. This particular substitution pattern might be too restrictive in certain choice settings.

Hausman and McFadden (1984) suggested that if a subset of the choice set truly is irrelevant, the estimation without it is inefficient but does not lead to inconsistency. However, if the remaining odds ratios are not truly independent from these alternatives, the parameter estimation obtained when these choices are excluded will be inconsistent.

To test the IIA of the alternatives using the Hausman-McFadden method (1984), the logit model needs to be estimated twice under a full set of alternatives and a specified subset of alternatives separately. If IIA holds, the two sets of estimates should not be statistically different. Let β_a denote the estimates obtained from the full set of alternatives, and Ω_a denote their estimated covariance matrix. Let β_b denote the estimates of the same parameters obtained from the specified subset of alternatives and $\Omega_b$denote their estimated covariance matrix accordingly (Some parameters that can be estimated in the full set may not be identified in the subset, in which case β_a refers to estimates under setup of the sub vector of parameters that are identified in both setups). Then the quadratic form

$$(\beta_a - \beta_b)'(\Omega_b - \Omega_a)^{-1}(\beta_a - \beta_a) \tag{3-32}$$

has a chi-square distribution when IIA is true. The degree of freedom of the chi-square test equals the rank of $(\Omega_b - \Omega_a)$.

3.2.3.4 Nested logit models

If the IIA test fails, a natural alternative is a multivariate probit model (Greene, 2003). Because of the practical difficulty of computing the multinomial integral and estimation of an unrestricted correlation matrix, the multivariate probit model is not popular in practice. The nested logit model, which relaxes the homoscedasticity assumption and groups the alternatives into subgroups that allow the variance to differ across the groups while maintaining the IIA assumption within the groups, provides an intuitively appealing structure (Greene, 2003).

In the liner shipping market, a company may first choose a new or second-hand ship before deciding on the size of the ship, or it may first choose a size of ship to invest before considering its type, whether new or second-hand. In each of the scenarios of type priority and size priority structures, a shipping company first decides the investment on the first level (type or size), and then select a particular type of ship on the second level (size or type).

Suppose that the utility for company i to select a specific ship type j, U_{ij}, is determined by the observable utility that contains a nest-specific utility w_{ik} and an alternative-specific utility z_{ij}, and the unobservable random utility ε_{ij}, that is,

$$U_{ij} = w_{ik} + z_{ij} + \varepsilon_{ij} \tag{3-33}$$

The common method of estimating a nested logit model is the MLE estimator, in which defining the likelihood function is the first step. The process of defining such a function is as follows. First, the conditional probability for choosing the alternative j in the nest k is

$$P_{ij|k} = e^{\frac{z_{ij}}{\tau_k}} \Big/ \sum_{j=1}^{J_k} e^{\frac{z_{ij}}{\tau_k}} , \tag{3-34}$$

where τ_k is the coefficient to be estimated, and J_k is the number of alternatives in nest k. Second, the probability for choosing the nest k can be written as:

$$P_{ik} = \frac{e^{w_{ik} + \tau_k \widetilde{U}_{ik}}}{\sum_{l=1}^{K} e^{W_{il} + \tau_l \widetilde{U}_{il}}} \tag{3-35}$$

where K is the total number of nests in the model; $\widetilde{U}_{ik} = \ln\left[\sum_{j=1}^{J_k} e^{Y_{ij}/\tau_k}\right]$ is the inclusive value; and $\tau_k \widetilde{U}_{ik}$ is the expected utility the company obtains from selecting an alternative in nest k. Then the likelihood for the company i to choose the alternative j is

$$P_{ij} = P_{ij|k} \cdot P_{ik} \ . \tag{3-36}$$

Mcfadden (1978) has shown that if $\tau_k \notin [0,1]$, the model may provide unacceptable representations of behavior. In other words, the assumption on the nested structure is not appropriate for modeling the decision making process. Thus, it is possible to use this to test whether the nested structure for a given problem is appropriate.

For the estimation of the nested logit model, the full information maximum likelihood (FIML) estimation is more efficient (Greene, 2003), in which the log-likelihood is

$$lnL = \sum_{i=1}^{n} \ln\left[Prob(alternative|level) \times Prob(level)\right]_i = \sum_{i=1}^{n} P_{ij|k} P_{ik}. \tag{3-37}$$

3.3 Panel data analysis

In the analysis of the company's capacity expansion, the data is collected from both cross-sectional units and over time. This type of data is known as panel data or cross-sectional time-series data. The fundamental advantage of a panel data set over a cross section is that it allows great flexibility in modeling differences in behavior across individuals over time (Greene, 2003). The basic framework for this discussion is a regression model of equation (3-38):

$$y_{it} = x_{it}'\beta + z_i'\alpha + \varepsilon_{it} \tag{3-38}$$

ε_{it} is i.i.d. (independently and identically distributed) distributed with 0 mean. There are k regressors in x_{it}, not including a constant term. The heterogeneity, or individual effect is $z_i'\alpha$ where z_i contains a constant term and a set of individual variables or group specific variables, which may be observed (such as firm scale) or unobserved (such as individual investment strategy) all of which are taken to be constant over time t.

3.3.1 Fixed effect model

If z_i contains only a constant term, then OLS provides consistent and efficient estimates of α and the slope vector β. This means that the relationship between the dependent and explanatory variables is governed by the same regression coefficients for all cross-sectional units i (=1 …n) and time-periods t (=1…T).

If z_i is unobserved, but correlated with x_{it}, then the OLS of β is biased and inconsistent because of the omitted variable. In this instance, the fixed effects model is chosen (Equation 3-39), where Y and X are the matrix of dependent and independent variables for each firm over the time periods, $D = [d_1 \quad d_2 \quad \dots \quad d_n]$, and d_i is a dummy variable indicating the ith unit. It needs to be noticed that the term 'fixed' indicates that the individual effect does not vary over time, but not that it is nonstochastic.

$$Y = [X \quad d_1 \quad d_2 \quad \dots \quad d_n] \begin{bmatrix} \beta \\ \alpha \end{bmatrix} + \varepsilon = X\beta + D\alpha + \varepsilon\,, \qquad (3\text{-}39)$$

This model is usually referred to as the least squares dummy variable (LSDV) model. This LSDV model is a classical regression mode, which can be estimated by OLS or other efficient estimators such as the MLE method. When there are a large number of cross sections of n, the OLS estimator is likely to exceed the storage capacity of any computer. However, the computation can be reduced by using partitioned regression. Transforming the variable $X_* = M_D X$ and $Y_* = M_D Y$, the least squares estimator of β is now $b = [X'M_D X]^{-1}[X'M_D y]$, where $M_D = I - D(D'D)^{-1}D'$. Then the dummy variable coefficients can be recovered from the normal equation in the partitioned regression, $a = [D'D]^{-1}D'(y - Xb)$.

To test the appropriateness of the pooled model and the fixed effect model or the differences across firms, the null hypothesis that the constant terms are all equal can be tested using an F test,

$$F(n-1, nT-n-k) = \frac{(R^2_{Fixed} - R^2_{Pooled})/(n-1)}{(1-R^2_{Fixed})/(nT-n-k)}. \tag{3-40}$$

Where *Fixed* indicates the fixed effect model and *Pooled* indicates the pooled or restricted model with only a single overall constant term.

3.3.2 Random effect model

If z_i is uncorrelated with x_{it}, then the model can be formulated as

$$\begin{aligned} y_{it} &= x'_{it}\beta + E[z'_i\alpha] + \{z'_i\alpha - E[z'_i\alpha]\} + \varepsilon_{it} \\ &= x'_{it}\beta + a + u_i + \varepsilon_{it} \end{aligned}. \tag{3-41}$$

This is called random effect model, which specifies that u_i is a group specific random element, similar to ε_{it} except that it is unchanged for each group through time. The random effect model greatly reduces the number of parameters to be estimated. This model can be estimated using the popular estimation methods of Generalized Least Squares (GLE), Feasible Generalized Least Squares (FGLS), or the MLE method.

Assume:

$E[\varepsilon_{it} \mid X] = E[u_i \mid X] = 0,$

$E[\varepsilon^2_{it} \mid X] = \sigma^2_{\varepsilon},$

$E[u^2_i \mid X] = \sigma^2_u,$

$E[\varepsilon_{it} u_i \mid X] = 0 \textit{ for all i, t, and j,}$

$E[\varepsilon_{it}\varepsilon_{js} \mid X] = 0 \; if \; t \neq s \; or \; i \neq j,$

$E[u_i u_j \mid X] = 0 \; if \; i \neq j.$

Let $\eta_{it} = \varepsilon_{it} + u_i$, and $\eta_i = [\eta_{i1}, \eta_{i2}, \ldots, \eta_{iT}]'$. Then it can be calculated that,

$E[\eta_{it}^2 \mid X] = \sigma_\varepsilon^2 + \sigma_u^2,$

$E[\eta_{it}\eta_{is} \mid X] = \sigma_u^2, t \neq s,$

$E[\eta_{it}\eta_{js} \mid X] = 0 \; for \; all \; t \; and \; s \; if \; i \neq j.$

For unit i's T observations, let $\Sigma = E[\eta_i \eta_i' \mid X]$. Then

$$\Sigma = \begin{bmatrix} \sigma_\varepsilon^2 + \sigma_u^2 & \sigma_u^2 & \sigma_u^2 & \cdots & \sigma_u^2 \\ \sigma_u^2 & \sigma_\varepsilon^2 + \sigma_u^2 & \sigma_u^2 & \cdots & \sigma_u^2 \\ & & \cdots & & \\ \sigma_u^2 & \sigma_u^2 & \sigma_u^2 & \cdots & \sigma_\varepsilon^2 + \sigma_u^2 \end{bmatrix} = \sigma_\varepsilon^2 I_T + \sigma_u^2 i_T i_T'. \tag{3-42}$$

As observations i and j are independent, the disturbance covariance matrix for the full nT observations is

$$\Omega = \begin{bmatrix} \Sigma & 0 & 0 & \cdots & 0 \\ 0 & \Sigma & 0 & \cdots & 0 \\ & \cdots & & \vdots & \\ 0 & 0 & 0 & \cdots & \Sigma \end{bmatrix} = I_n \otimes \Sigma. \tag{3-43}$$

Based on the above expression, the GLS estimator of the slope parameters is

$$\hat{\beta} = (X'\Omega^{-1}X)^{-1}X'\Omega^{-1}y = \left(\sum_{i=1}^{n} x_i'\Omega^{-1}x_i\right)^{-1}\left(\sum_{i=1}^{n} x_i'\Omega^{-1}y_i\right). \qquad (3\text{-}44)$$

If the variance components in Equation 3-42 are known, the GLS estimator based on the true variance matrix is the best linear unbiased estimator (BLUE). In many situations, the variance matrix is unknown, and then the feasible generalized least squares (FGLS) is more useful in such situations. The disturbance variances first need to be estimated and then applied into the GLS estimator. The unbiased estimators of the disturbance variance components, σ_ε^2 and σ_u^2 in Ω, are the residual variance estimators in the LSDV regression and the pooled regression respectively. Baltagi (1995a) and Greene (2003) have proved that the FGLS estimator in random effect models is unbiased, consistent, efficient, and asymptotically normally distributed.

Since the likelihood function is complicated, it is not illustrated here. Readers can find detailed descriptions of the MLE estimator in Baltagi's books (1995a; 1995b). As Greene (2003) stated, in a large sample set none of the other estimators would have better asymptotic properties than the MLE or FGLS estimators.

To test the appropriateness of the random effect model, the null hypothesis that there are no variances across companies can be tested using the Lagrange multiplier test,

$$LM = \frac{nT}{2(T-1)}\left[\frac{\sum_{i=1}^{n}\left[\sum_{t=1}^{T} e_{it}\right]^2}{\sum_{i=1}^{n}\sum_{t=1}^{T} e_{it}^2} - 1\right]^2 . \qquad (3\text{-}45)$$

Under the null hypothesis, *LM* is a chi-squared distribute with one degree of freedom (Greene, 2003).

3.3.3 Specification test for random effect and fixed effect models

The fixed effect model and the random effect model can be used under different situations as stated above. However, in reality it is difficult to tell whether the individual effects are correlated with other independent variables. In dealing with this, Hausman's specification test (Greene, 2003) can be used to test for the appropriateness of selecting random or fixed effect models. The test is based on the idea that under the null hypothesis of no correlation, both random and fixed effect estimators are consistent, but that the fixed effect estimate is inefficient. Under the alternative hypothesis, the fixed effect estimate is consistent, but the random effect is not. Therefore, under the null hypothesis of no correlation, the estimator

$$W = \chi^2[k] = [b - B]'[Var(b) - Var(B)]^{-1}[b - B] \ , \qquad (3\text{-}46)$$

is chi-squared distributed with k degrees of freedom. In which b are the estimates from the fixed effect model and B are the estimates from the random effect model.

3.4 Sources of data

The data for this thesis are from three main sources. The first data source is the Clarkson Shipping Intelligence Network (CSIN) (2010). It provides historical data on market fleets, newbuildings, second-hand sales, time charter rates, newbuilding prices, and second-hand prices.

The second data source is the Drewry annual container market review and forecast from 2000 to 2010 (2000, 2002-2008, 2010) and its quarterly report from 2007 to 2010 (2007Q1-2010Q3), which provides annual and quarterly time series data on world container throughput.

The CSNI and Drewry databases provide the market data for dynamic analysis of the container shipping market movement for Research Question 1.

The third important data source is the Alphaliner (2010) container liner database. It contains data about all the operators in the world container liner market, including their annual fleets, orders for new vessels, and purchase of second-hand vessels. It also provides more detailed information about the top 100 operators in each year, with their number of ships, total fleet and vessels chartered from chartering market. According to Alphaliner, the top 100 liner companies control more than 90 per cent of the world’s container capacity. Because the top 100 companies are different each year, only 153 companies are involved in the analysis of liner companies’ capacity expansion and investment behavior for Research Questions 2, 3 and 4.

The combined data from CSNI, Drewry and Alphaliner provides an excellent opportunity to apply the dynamic market analysis and examine the container liner companies' capacity expansion, ship investment decisions, and ship choice behavior as a function of company attributes, market conditions and investment strategies.

Chapter 4: Dynamic analysis of liner market

4.1 Introduction

The importance of the shipping cycle in both private business operation and public sectors has, unsurprisingly, motivated numerous efforts to understand, describe, model, and predict the fluctuation of the shipping freight rate. Martin Stopford (2009), for example, described the shipping cycle in the past 266 years, discussed its characteristics, frequency, and prediction difficulties. Freight market analysis is the first area for applied econometrics. Tinbergen and Koopmans, two well-known pioneers in the econometrics, actually started econometric analysis in shipping (Beenstock & Vergottis, 1993). Tinbergen (1959) investigated the sensitivity of freight rates to changes in demand and supply. Koopmans (1939) proposed the first theory to forecast tanker freight rates, assuming market equilibrium between demand and supply. He explained the dynamic behavior of the tanker market by investigating the interrelationship between the market size, freight rate, and shipyard's activity. Since then, many different models have been developed for the tanker and bulk market analysis. Beenstock and Vergottis (1989a; 1989b; 1993) developed a market equilibrium model assuming explicitly profit optimization on the supply side, and perfect competition on the demand. They tested the model for the tanker and dry bulk shipping markets using annual data. This work is recognized as a milestone in econometric analysis of shipping market that "heavily influenced" the modern analysis of the bulk shipping market (Glen, 2006). The most recent work that follows BV's model is Tvedt (2003), who combined structural and econometric stochastic methods, and built a continuous stochastic partial equilibrium model for the freight and new building markets. He found that the equilibrium freight rate process is close to that of a standard geometric mean reversion process.

Despite the significant contribution of container shipping in world seaborne trade, literature on economic modeling and statistical analysis of the container shipping market is scarce. This chapter fills the gap by building a dynamic-economic model for the container shipping market and testing it using annual data from the past 29 years. Furthermore, it reveals the significance of collective market adjustment principles using the observed data, without involving complexities in individual behavior analysis, such as market competition strategies, speculation, and hedging.

4.2 Theoretical model

It is well recognized that the container shipping market is characterized by a high level of concentration, which can be exemplified by the statistics that shows some 48% of the market share is carried by the 3 largest global alliances (Grand Alliance, the CHKY Alliances and the New World Alliance) and Maersk Line (Containerization International, 2008). This certainly is a distinctive nature compared with the bulk and tanker market. However, whether this level of concentration is sufficient to sustain monopoly behavior in the container shipping market is still debatable. Sys (2009) suggested that the container shipping industry is operating in an oligopoly market; while Haralambides (2004) argued that it is the accessibility of the market to new or potential competitors that determines its contestability. A discussion about the behavior of liner shipping market can be found in Shashikuma (1995).

Instead of judging the nature of the liner shipping market, this chapter builds a model based on the hypothesis about the market behavior, and tests it using the observed market data. Next is the explanation of the formulation procedure of the model.

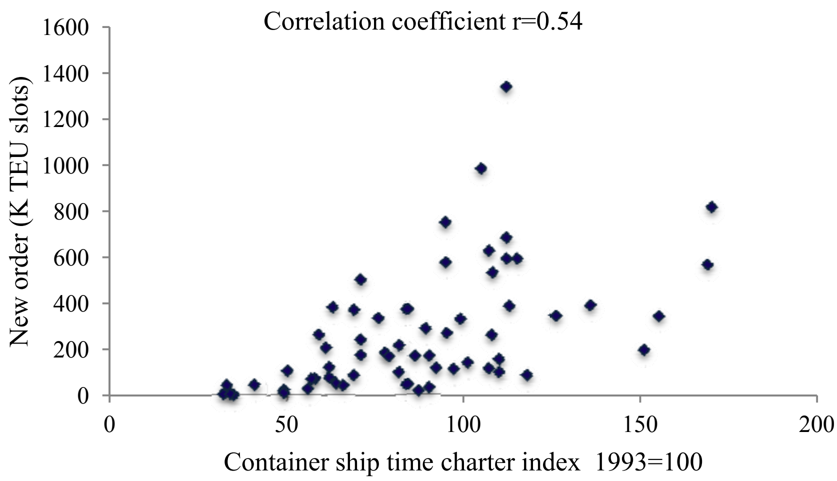
As in the dry bulk and tanker markets, the container shipping market also include second-hand market, new-building market and scrapping market. Several assumptions are made to simplify the model and focus on the freight market.

First, as the container shipping industry is relatively new and the life time of the early container vessel is usually about 30 years, the scrapping activity has only started recently and the size of the scrapping is just a small fraction of the total world fleet size. The average proportion of demolition to world container fleet capacity was only 0.763% from 1994 to 2009. Thus the impact of scrapping on the container fleet capacity can be ignored.

Secondly, it is assumed that the second hand market will not affect the container freight market. As trade in the second hand market does not change the usage of a container vessel, it does not affect the world container fleet capacity.

To further simplify the model, it is assumed that the new building market will not affect the container freight market. It is recognized that there are many decision variables when a shipping company considers placing a new order. Among them, the main decision variable is the freight rate, not the new building price. Statistics show that there is a high positive correlation between new building orders and freight rate, as depicted in figure 4-1. Most of the new orders are made when the freight rate is high, which is often the time when the price of the new building is high.

Figure 4-1: Correlation between time charter rate and new orders (1996-2010)



The above assumptions enable this section to focus on the freight market, i.e., model the fluctuation in freight rate from the interaction between demand for container shipping services, and its supply measured by the total world fleet capacity (in TEU slots). The change in world container fleet capacity with the industrial profit is modeled first. As a high freight rate is a good indicator of high industrial profit, it is first postulate that the total number of new orders N_t at year t is proportional to the overall industrial profit of that year, i.e.,

$$N_t=\eta\cdot Profit_t\ , \tag{4-1}$$

where η is the average proportion of profits spent on purchasing new ships, and the $Profit_t$ follows the common definition:

$$Profit_t = P_t Y_t - c_1 X_t - c_2 OIL_t \,, \tag{4-2}$$

where Y_t is the total number of containers carried, P_t the market freight rate per TEU, X_t the world container fleet capacity (in TEU slots), OIL_t the bunker price, $c_1>0$ the constant marginal/average cost per fleet capacity (in TEU slots), and $c_2>0$ the profit adjustment factor for the bunker price.

For simplicity, the average lag (θ) is used to represent the time from a new order to delivery. Then the change of the world container fleet capacity can be expressed as:

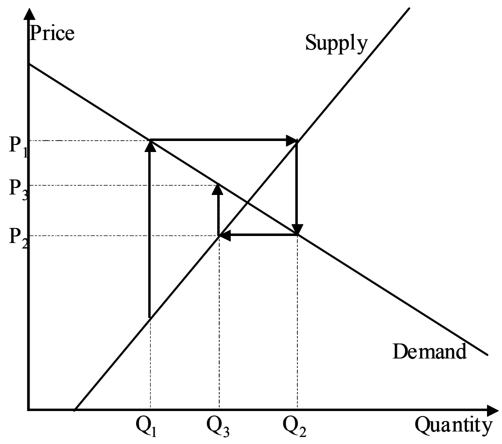
$$\Delta X_t = N_{t-\theta}, \tag{4-3}$$

where $\Delta X_t = X_t - X_{t-1}$. By putting equations 4-1 to 4-3 together, the world shipping fleet dynamic equation can be specified as:

$$\Delta X_t = \eta \cdot (P_{t-\theta} Y_{t-\theta} - c_1 X_{t-\theta} - c_2 OIL_{t-\theta}). \tag{4-4}$$

Next it is the description how the freight rate changes with the demand for container shipping, and the world fleet capacity. The change of market price due to the change in demand and supply, a fundamental economic problem, has been well studied in the literature. When there is no short-term flexibility in demand and supply, the delayed response to the excessive demand or supply can also result in price oscillation. Kaldor (1934) used the well-known Cobweb model (figure 4-2) to describe the price change with alternative excessive demand and excessive supply.

Figure 4-2: The cobweb model



When the market price is high at time 1, the quantity demanded (Q_1) at P_1 is lower than the quantity supplied (Q_2). The excessive supply (Q_2-Q_1) will reduce the price to P_2 in the next period. At this price level, the quantity demanded (Q_2) is higher than the quantity supplied (Q_3). This excessive demand (Q_2-Q_3) will increase the price. The stability of the market price in the long run will depend on the relative price sensitivity of demand and supply. According to this theory, the change of market price can be written as:

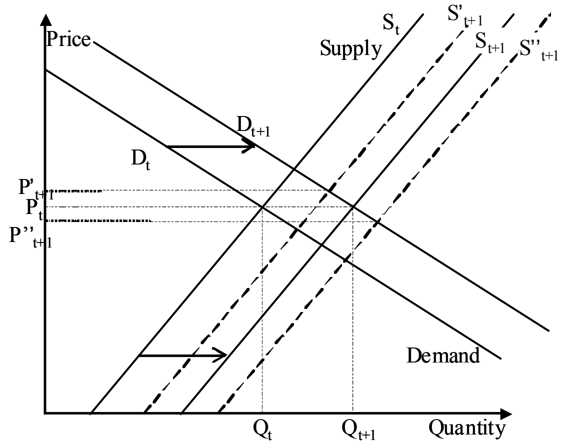
$$\Delta P_{\mathrm{t}}=\delta(Y_t-\varphi X_{\mathrm{t}}), \tag{4-5}$$

where $\Delta P_{\mathrm{t}}=P_t-P_{t-1}$, the price change in year t, and φ the reuse rate of a TEU slot. This equation states that price will increase when there is excessive demand, and drop with excessive supply.

Considering the nature of maritime transportation for containerized goods, first, shipping freight rate is flexible and negotiable between the shipper and carrier. Second, it is well-known that the marginal cost for an additional container, especially in liner services, is very low. Container carriers can always accept one more box as long as it covers the marginal cost. Third, there are many ways to provide short-term shipping services when facing a sudden demand increase, including increase loading factors and increase cruise speed. Thus, demand and supply are both flexible enough in container shipping industry, especially on an annual level. This conforms to BV's model assumption in market equilibrium in his econometric analysis for the dry bulk and tanker markets (Beenstock & Vergottis, 1993).

Assuming market clears each year, the freight rate changes with exogenous demand shift caused by the exogenous change in international trade, and the supply shift as more container vessels are added to the world container fleet capacity. From the demand side, with the increase in international trade, the demand for container shipping increases even when the market freight rate is constant. On the supply side, when more capacity is added to the industry, more container ships are available in the market to provide more services even at the same market price. An illustration of how market price changes with relative shifts in demand and supply are given in Figure 4-3.

Figure 4-3: Illustrated price dynamics with demand and supply shift



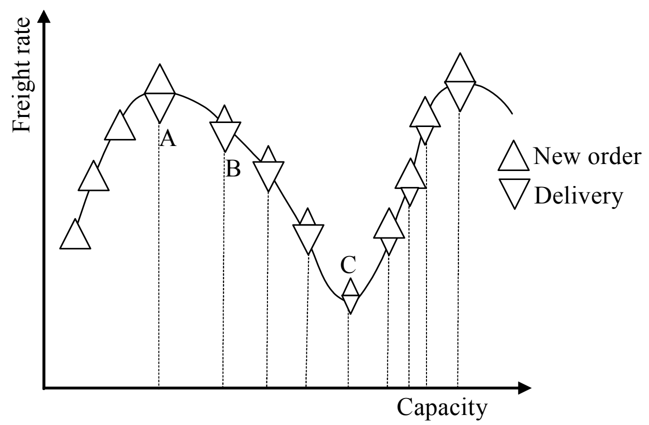
Assuming at time t, the market clearing price and quantity are (P_t, Q_t), the intersection of demand D_t and supply S_t. If there are equal amount of supply and demand shifts ($D_t \rightarrow D_{t+1}$, $S_t \rightarrow S_{t+1}$), The new market clearing price remains unchanged, while the quantity changes to Q_{t+1}. This confirms to the description by Tvedt (2003). If the supply only moves to S'_{t+1}, less than the demand shift, the market clearing price increases to P'_{t+1}. On the other hand, if the supply moves to S''_{t+1}, more than the demand shift, the market clearing price drops to P''_{t+1}. Applying this to the container market freight rate with respect to the supply and demand change, it is postulated:

$$\Delta P_t = \delta(\Delta Y_t - \varphi \Delta X_t), \tag{4-6}$$

where ΔY_t is the change in the total number of containers handled, $\varphi>0$ is a constant representing *the average annual container slot reuse rate*, and $\delta>0$ is the price adjustment factor due to the demand and supply shifts.

Equations (4-4) and (4-6) are the two dynamic equations that describe the two major forces in the container shipping market. The interaction of these two forces can be illustrated in Figure 4-4. It is assumed that the market demand for container shipping increases exogenously. When the price is high (at A in Figure 4-4), the high industry profit will bring up the number of new orders (denoted by larger upper triangles). If the delivery of new container ships results in a larger increase in capacity than that in demand, the market price falls. When this happens (at B), there would be very few new orders (denoted by smaller upper triangles) by the speculators, but the ships ordered in the previous two or three years when the freight rate increases keep adding to the existing fleet, which would accelerate the decreasing rate of the freight rate. This downward trend in the market freight rate would end when the capacity increases slower than the demand increase (at point C where the delivery is very small). Because of the few new orders during the previous three or four years, the low supply in shipping capacity pushes up the market price. When the market price increases, there would be a stronger incentive to order more new container vessels again, which leads to a new shipping cycle.

Figure 4-4: Illustration of shipping market dynamics



To test the model, using the annual data for container market freight rate, the total number of containers handled, the world fleet capacity in TEU slots, and the bunker price from 1980 to 2009, the parameters in the statistical model are estimated using the above data, which will be explained in the next section.

4.3 Description of the data and variables

Demand for container transportation services is derived demand from global trade, which is determined by the comparative advantage of individual countries. Demand is taken as given to avoid modeling the global trade. Besides this, as unsatisfied demands are not observable, the assumption on market clearance each year enables to use the container throughput as quantity demanded. The data used in this chapter and their sources are included in table 4-1. This study was first modeled and published in 2009 with the updated report from Drewry (2007), in which the container throughput in 2008 is estimated by Drewry. The data has been renewed to include the values in 2009 now. Since there are great differences between Drewy's predicted and actual values in 2008, these two models estimated with 80-08 (predicted values in 2008) and 80-09 data are both analyzed in the following analysis.

Table 4-1: Data used in this chapter and sources

Year	Container Throughput (Yt; K TEU)*	Freight rate (Pt; $/TEU)*	Fleet Capacity (Xt; K TEU)*	Bunker Price (OILt; $/ton)%	Delivery (Nt; K TEU) %	Scrap (St; K TEU) %	New Order (Ot; K TEU) %
1980	38,821	1,762	665.0	307	115.8		
1981	41,900	1,644	702.0	288.3	38.3		
1982	43,800	1,449	745.0	284.8	72.6		
1983	47,600	1,441	799.0	243.7	100.6		
1984	54,600	1,451	883.0	229.6	130.3		
1985	56,170	1,420	1,012.0	222.8	131.1		
1986	62,200	1,355	1,189.0	142.1	140.1		
1987	68,300	1,455	1,276.3	144.1	92.7		
1988	75,500	1,630	1,384.7	124.7	116.4		
1989	82,100	1,632	1,487.9	144.1	102.3		
1990	88,049	1,544	1,613.2	191.2	133.6		
1991	95,910	1,544	1,756.0	170.8	152.1		
1992	105,060	1,471	1,916.3	161.9	167.6		
1993	114,920	1,480	2,101.3	150.5	200.1		115.9
1994	129,380	1,466	2,370.7	133.2	268.8	2.8	472.5
1995	144,045	1,519	2,684.0	140.6	330.1	10.9	597.4
1996	156,168	1,434	3,048.1	175.1	408.1	21.5	501.5
1997	175,763	1,282	3,553.0	157.2	523.1	25	203.6
1998	190,258	1,267	4,031.5	112.2	529.6	87.3	414.5
1999	210,072	1,385	4,335.2	133	257.1	51.7	555.2
2000	236,173	1,421	4,799.1	231.6	449.1	15.5	956.9
2001	248,143	1,269	5,311.0	192.4	623.2	36.1	519.1
2002	277,262	1,155	5,968.2	188.2	642.8	66.5	414.2
2003	316,814	1,351	6,528.6	230.4	560.7	25.7	2057
2004	362,161	1,453	7,162.8	313.4	643	4	1652.9
2005	397,895	1,491	8,117.0	458.4	941.5	0.3	1644.3
2006	441,231	1,391	9,472.0	524.1	1366.6	20.4	1784.6
2007	496,625	1,435	10,805.0	571.3	1321.1	23.8	3060.1
2008$	540,611	1,375	12,126.0	850.7			
2008	525,285	1,580	12,099.0	850.7	1478.2	100.1	1091.9
2009	476,088	1,107	12,709.0	490.6	1128	376.1	94.7

Source: * The Drewry Annual Container Market Review and Forecast 2000, 2002-2008, 2010.
% Clarkson Shipping Intelligence Network (CSIN) (2010).
$ Predict values from Drewry Annual Container Market Review and Forecast (2007).
Note: Freight rates (in italic) computed from general freight index (from Shipping Statistics Yearbook (2007).

The world container throughput, from the Drewry Annual Container Market Review and Forecast, is the total port throughput, including the empty and transhipment containers. Container throughput is used, not the world trade volume, as the demand for container shipping services, for the following two reasons. First, the world trade volume includes many commodities that are not carried by ships. Furthermore, not all the seaborne trade is containerized and the containerization rate is changing. As a result, to convert world trade volume of different commodities to a number of TEUs is not currently feasible. Secondly, container throughputs are a more appropriate data to use. Although there are empty containers, transhipments and possible double counting, they are actually part of the demand for container transportation services. Thus, container throughput is used, rather than the world trade volume, as the demand for container transportation services.

The same report from Drewry also provides the container freight rate, which is the weighted average of Transpacific, Europe-Far East and Transatlantic trades, inclusive of THCs (Terminal Handing Charge) and intermodal rates. This variable is a synthetic index, representing the average level of container freight rates. This can be an index for shipowners' unit revenue. As Drewry only reported freight rates from 1994-2009, the missing period (1980-1993) has to be calculated from the General Freight Index in the Shipping Statistics Yearbook 2009, using a simple statistical equation between container freight rate and the general freight index from 1994 to 2009. The container fleet capacity data are also from the Drewry Annual Container Market Review and Forecast.

On the supply side, the data from Clarkson Research Services Limited 2010 is used, which include the new order, delivery, and scrapping data in TEU slots and bunker prices. Although some of these data are not used to estimate the main model, they are used to determine whether to include the scrapping market and the shipbuilding lag. Therefore, they are also included in the table.

4.4 Empirical results and discussion

The statistical model is constructed by transferring equations (4-4) and (4-6) into linear forms as follows:

$$\Delta X_t = \eta\, P_{t-\theta}Y_{t-\theta} - \eta\, c_1X_{t-\theta} - \eta\, c_2OIL_{t-\theta} + \varepsilon_{1t} = \alpha_1P_{t-\theta}Y_{t-\theta} - \alpha_2X_{t-\theta} - \alpha_3OIL_{t-\theta} + \varepsilon_{1t}, \quad (4\text{-}7)$$

$$\Delta P_t = \delta\Delta Y_t - \delta\varphi\Delta X_t + \varepsilon_{2t} = \alpha_4\Delta Y_t - \alpha_5\Delta X_t + \varepsilon_{2t}\,. \quad (4\text{-}8)$$

The last term ε_{it} in each equation is the error term. Although $Y_{t-\theta}$ appears in equation (4-7) and Y_t appears in equation (4-8), they are not contemporaneously correlated, so equation (4-7) can be estimated by itself. As ΔX_t appears on the left-hand side of equation (6-7) and the right-hand side of equation (4-8), the error terms are not independent (cov(ΔX_t, ε_{2t})=σ_{12}). Thus the Simultaneous Equation (SE) method is applied to estimate the coefficients in the system. The first step in the SE is to rewrite equations (4-7) and (4-8) as reduced forms by expanding the ΔX_t in equation (4-8):

$$\Delta X_t = \pi_1P_{t-\theta}Y_{t-\theta} - \pi_2X_{t-\theta} - \pi_3OIL_{t-\theta} + \varepsilon_{1t}\ , \quad (4\text{-}9)$$

$$\Delta P_t = \alpha_4\Delta Y_t - \alpha_5\alpha_1P_{t-\theta}Y_{t-\theta} + \alpha_5\alpha_2X_{t-\theta} + \alpha_5\alpha_3OIL_{t-\theta} + \alpha_5\varepsilon_{1t} + \varepsilon_{2t}$$

$$= \pi_4\Delta Y_t - \pi_5P_{t-\theta}Y_{t-\theta} + \pi_6X_{t-\theta} + \pi_7OIL_{t-\theta} + \pi_8\varepsilon_{1t} + \varepsilon_{2t}. \quad (4\text{-}10)$$

As can be seen from the reduced form, the two equations are not independent. Thus, the two stage least square (2SLS) is not sufficient to make full use of the correlation between error terms. Therefore, the 3SLS method was applied in the estimation process for the coefficients in the reduced form. The estimated parameters are transferred back to the structural equation. The instrument variables used in the 3SLS include all the exogenous variables and predetermined variables.

4.4.1 Specification of construction lag θ

As a key factor in shipping market analysis, the shipbuilding lag is ubiquitous in almost all the econometric analysis in this field. Binkley and Bessler (1983) found that the shipbuilding construction lag, ranging from eight months to around two years, is one of the most important market features in the bulk shipping market analysis. Here, constant construction lag is assumed during the study period. Furthermore, as it is using annual data, the lag is required to be rounded to an integer. Therefore, six statistical equations between the delivery and the new order data are constructed, and the most significant one is selected to use in the model.

The regress results of the 6 equations are listed in table 4-2. The 2-year lag and 3-year lag are all significant in models 1-6, but R^2 in model 5 is much bigger than that in model 6, so θ=2 is chosen. This means on average it takes two years to build a container vessel, although bigger ships may take longer and smaller ones may only need several months.

Table 4-2: Modeling of construction lags (p-value in parenthesis)

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
b_0	255.5099	257.6291	175.4902	218.035	297.841	356.7358
	(0.0436)	(0.0174)	(0.0061)	(0.0035)	(0.0022)	(0.004)
$order_t$	-0.00475					
	(0.9475)					
$order_{t-1}$	0.167043	**0.166467**	0.112564			
	(0.0596)	**(0.0327)**	(0.0444)			
$order_{t-2}$	**0.211811**	**0.210334**	**0.251027**	**0.313896**	**0.434595**	
	(0.0361)	**(0.0152)**	**(0.0021)**	**(0.0007)**	**(0.0003)**	
$order_{t-3}$	**0.27146**	**0.26916**	**0.267692**	**0.279653**		**0.441905**
	(0.0156)	**(0.0037)**	**(0.0013)**	**(0.0028)**		**(0.0043)**
$order_{t-4}$	-0.20405	-0.212				
	(0.3479)	(0.1867)				
R-squared	0.966885	0.966844	0.954026	0.914724	**0.745311**	0.615101

4.4.2 3SLS results of the system parameters

The regression result from the 3SLS process for the structure equation, including the estimates of the structural parameters and their corresponding t-values, R^2 and adjusted R^2 are listed below:

Model 1: 80-08 model

$$\Delta X_t = 0.0000034 P_{t-2} Y_{t-2} - 0.06411 X_{t-2} - 0.438215 OIL_{t-2}$$
$$(5.00) \qquad (-1.52) \qquad (-2.72) \quad \text{t-value}$$

R^2=0.95, Adjusted R^2=0.947, SSE_1=200 197, SST_1=4 125 572

$$\Delta P_t = 0.00894 \Delta Y_t - 0.378085 \Delta X_t$$
$$(3.96) \qquad (-4.01) \quad \text{t-value}$$

R^2=0.353, Adjusted R^2=0.328, SSE_2=158 424, and SST_2=245 222

All the estimated coefficients (a_1 through a_5 in equations 4-7 and 4-8) are significant at, at least 90% confidence level, and the coefficient estimates on revenue (a_1), bunker (a_3), demand (a_4) and supply (a_5) are all significant at 99% confidence level.

Model 2: 80-09 model

$$\Delta X_t = 0.0000048 P_{t-2} Y_{t-2} - 0.167268 X_{t-2} - 0.662719 OIL_{t-2}$$
$$(3.84) \qquad (-2.17) \qquad (-2.21) \quad \text{t-value}$$
R^2=0.818, Adjusted R^2=0.804, SSE_1=746 590.1, SST_1=4 125 572

$$\Delta P_t = 0.005266 \Delta Y_t - 0.205345 \Delta X_t$$
$$(4.63) \qquad (-4.16) \quad \text{t-value}$$
R^2=0.477, Adjusted R^2=0.457, SSE_2=250 317.7, SST_2=478 754.4

All the estimated coefficients are significant at, at least 95% confidence level, and the coefficient estimates on revenue (a_1), demand (a_4), and supply (a_5) are all significant at 99% confidence level.

To evaluate the overall explanatory power of the whole system, an overall coefficient of determination for this system is constructed using the error sum of squares (SSE) and total variance (SST) in the respective regression equation. The expression for the overall R^2 and its value for 80-08 model and 80-09 model are:

$$R^2 = 1 - \frac{SSE_1 + SSE_2}{SST_1 + SST_2} = 0.9169 \text{ (80-08 model) and } 0.7828 \text{ (80-09 model)},$$

which indicate the overall explanatory power of the system.

4.4.3 Explanation of the regression result

To understand the regression results, the 80-09 model is transformed back to the dynamic equations (4-4) and (4-6):

$$\Delta X_t = 0.0000048 P_{t-2} Y_{t-2} - 0.167268 X_{t-2} - 0.662719 OIL_{t-2}$$

$$= 0.0000048 (P_{t-1} Y_{t-2} - 34848 X_{t-2} - 138066 OIL_{t-2}) \qquad (4\text{-}11)$$

$$\Delta P_t = 0.005266\Delta Y_t - 0.205345\Delta X_t = 0.005266(\Delta Y_t - 39\Delta X_t) \qquad (4\text{-}12)$$

Thus the coefficients in equations (4-4) and (4-6) can be obtained from equations (4-11) and (4-12), which are listed in table 4-3.

Table 4-3: Summary of the parameters

Parameters	80-09	80-08	Meaning
η	0.0000048	0.0000034	Propensity for new order per dollar industrial profit (in TEU)
c_1	34 848	19 080	Average annual cost to operate one TEU slot (in US$)
c_2	138 066	130 421	Cost adjustment per unit increase in bunker price (in K US$)
δ	0.005267	0.00894	Price adjustment factor for Demand-Supply change ($/K TEUs)
φ	39	42	Annual productivity per TEU slot

The economic meanings of the estimated parameters are explained here. Parameter η is the propensity to order new ships or the increase rate of container capacity per dollar increase in industrial profit. The estimation indicates that 48 (34) TEU slots will be added to the capacity per US$10 million profit in the industry. Considering that the cost for a 3500TEU container vessel was about US$63 million in 2007 (Clarkson PLC, 2010), the result show that to order a container ship of that size, the total industrial profit has to be US$729 (1029) million. This implies around 8.6% (6.2%) of the earnings are used for building new ships.

Parameter c_1 is the annual average cost to own and operate one TEU slot. It is the total cost paid by a shipping company in the transportation process, as long as that process is covered by the freight rate. c_2 is the gross cost adjustment factor per dollar increase in bunker price for the whole industry, in thousands of US dollars. It indicates for a US$1 increase in bunker price, the operation cost for the whole industry will increase by about US $130 million. δ represents the price sensitivity for the relative annual increment in demand and supply. The result shows that if demand shifts by one hundred thousand or more in TEU slots than the shift in fleet capacity, there will be a 53 (89) cent increase in freight rate. The higher the δ, the more sensitive the freight rate is to the relative magnitude in demand and capacity change. φ is the capacity utilization factor, representing the annual reusing rate per TEU slot.

To test the stability of the regressed model, another two regression analyses using the same model is conducted applied to data from different time periods. The regression periods are from 1980 to 2006 and 1980 to 2007, respectively. The comparisons of the two additional regression results together with model 80-08 and 80-09 are shown in table 4-4.

Table 4-4: Comparison of parameter estimates using different observation range

	80-06		80-07		80-08		80-09	
Parameter	Estimates	t-value	Estimates	t-value	Estimates	t-value	Estimates	t-value
η	0.0000031	4.41	0.0000036	5.10	0.0000034	4.97	0.0000048	3.84
c_1	-11052	-1.21	-17107	-1.85	-19080	-1.53	-34848	-2.17
c_2	-91691	-2.71	-101684	-2.96	-130421	-2.72	-138066	-2.21
δ	0.0094	3.88	0.0091	3.78	0.0089	3.96	0.0053	4.63
φ	-45	-3.93	-43	-3.74	-42	-4.01	-39	-4.16

Table 4-4 indicates the parameter estimates are stable, and the t-values for all the parameters are all significant. Hence, first, it is predicable the estimated parameters in the model will not change much when there are more data observations in the future. Secondly, the stability in the parameter estimation and the t-value indicate the stability of the whole model and is free from the autocorrelation and heteroskedasticity. Therefore, the prediction reliability using the estimated model can also be assured in the next section.

4.5 Prediction of the estimated model

When market demand is exogenous, the container shipping fleet capacity and the market freight rate are the two most important variables in the container shipping market analysis. The specification of the model enables the prediction of the fleet capacity increases in two years based on the current container throughput, freight rate, and bunker price. The relative capacity increase, determined endogenously from the first dynamic equation, can then be used to predict the adjustment in freight rate, for given container transportation demand.

4.5.1 In-sample prediction

To demonstrate the explanatory power of the model, it first compares the model prediction with the actual data. An in-sample prediction for the market fleet capacity and the freight rate, together with the actual freight rate and fleet capacity from 1980 to 2008 (80-08 model) and 1980 to 2009 (80-09 model), are provided in Figure 4-5 and 4-6.

Figure 4-5: Comparison between the actual and predicted fleet capacities and freight rates (Model 80-08)

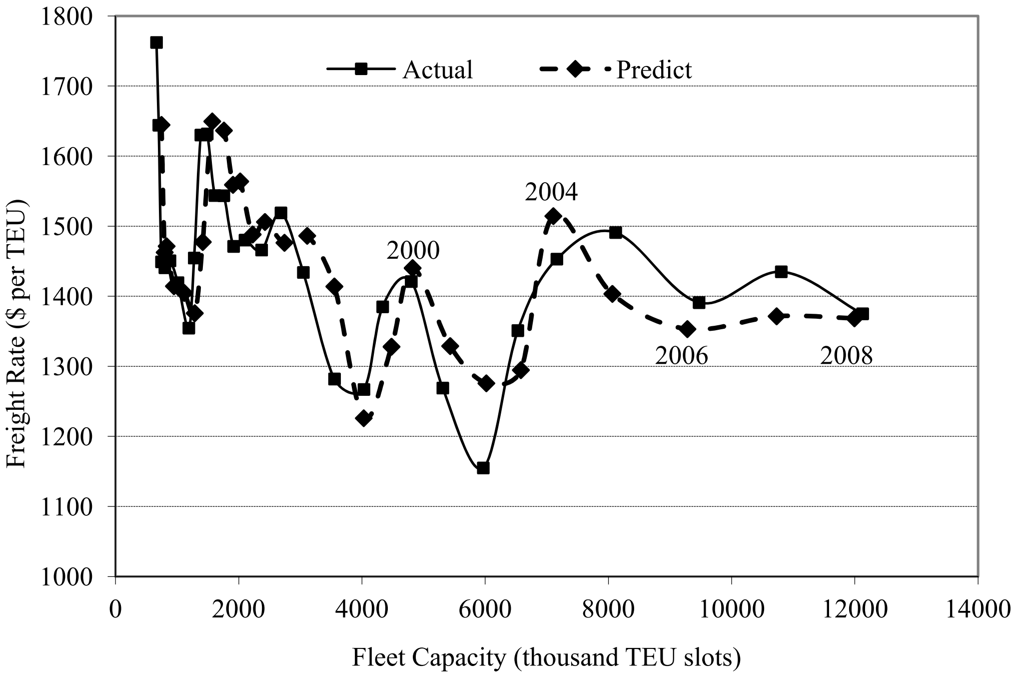


Figure 4-6: Comparison between the actual and predicted fleet capacities and freight rates (Model 80-09)

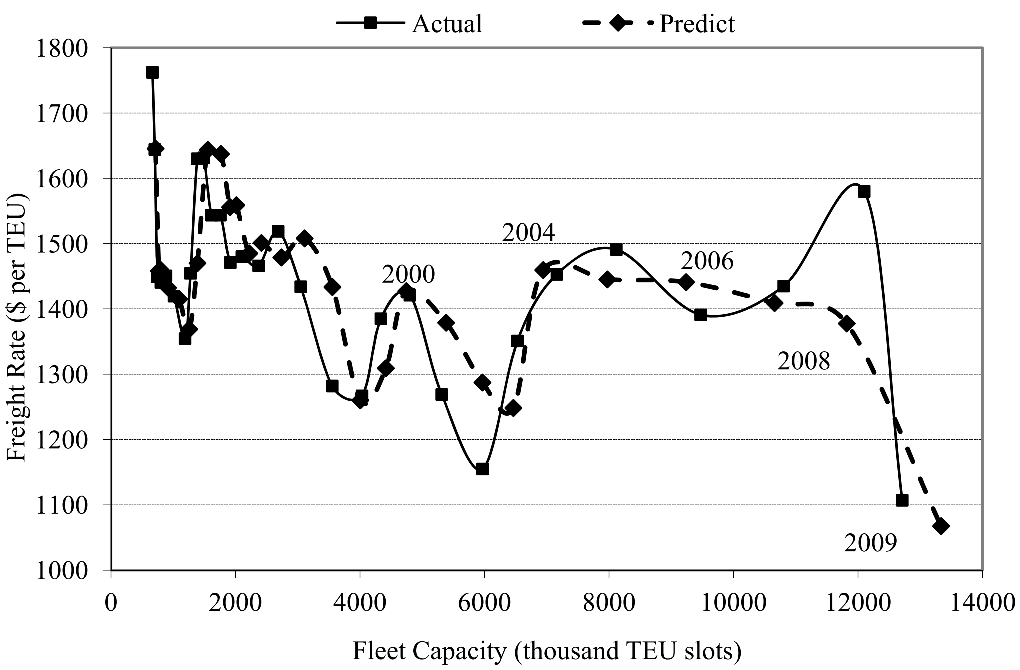


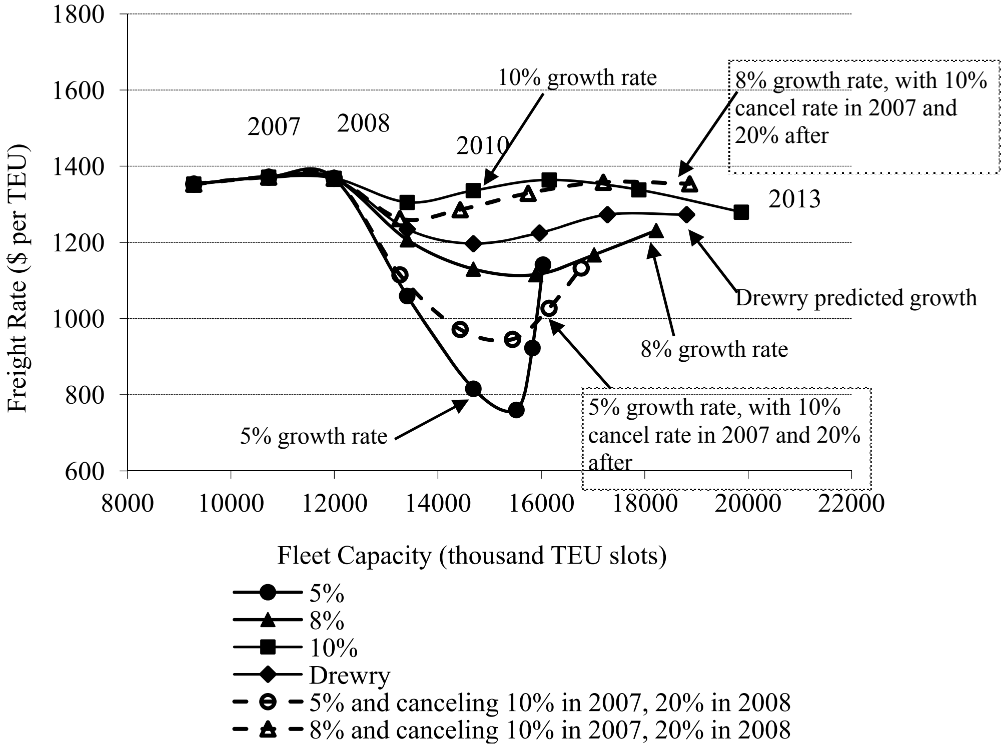
Figure 4-5 and 4-6 exhibit that the fleet capacity increased faster in recent years than the earlier years, as the horizontal distances between each pair of dots are wider in recent years. The freight rate generally decreases over time, and oscillates around the US$1400 in the later years. The prediction can largely replicate the trend of the actual freight rate change. The predicted fleet capacity each year is very close to the real fleet capacity (They are basically in the same vertical line).

4.5.2 Prediction for container shipping market

The purpose of this dynamic-economic model is to predict the future market situation, so that decision makers can anticipate and respond to possible market changes. The first necessary step is to assume the future container demand growth rate based on the past information. The data shows that the average increase rate of the container throughput in the past 29 years from 1981 to 2009 is about 9.1%, with the highest 14.3% in 2004, and the lowest -9.4% in 2009. Considering the possible range of container transportation demand in the coming years, three different growth rates (5%, 8% and 10%) are assumed from 2009 (2010 for model 80-09) to 2013.

During the current global financial crisis, the shipping sector has not only refrained from ordering new ships, but has also been motivated to cancel existing orders. According to recent statistics from Lloyd's Register, total new orders in October 2008 dropped by 90% compared with the same period in 2007. According to Clarkson, there were 94 new order cancellations at the same period. Cancellations can reduce the number of new deliveries to the market and slow down the freight rate decrease. As recent new orders are easier to cancel, a 10% cancellation rate is assumed for the new orders made in 2007, and a 20% cancellation rate for the new orders made in the following years. The continued cancellation after 2008 reflects the change in industry behavior for making new orders, a more prudent measure facing the financial crisis. The prediction of the market freight rate and the fleet capacity from 2009 (2010 for model 80-09) to 2013 are shown in figure 4-7 and 4-8. The actual data for 2007 and 2008 are included in the figure.

Figure 4-7: Forecast of the container shipping market from model 80-08



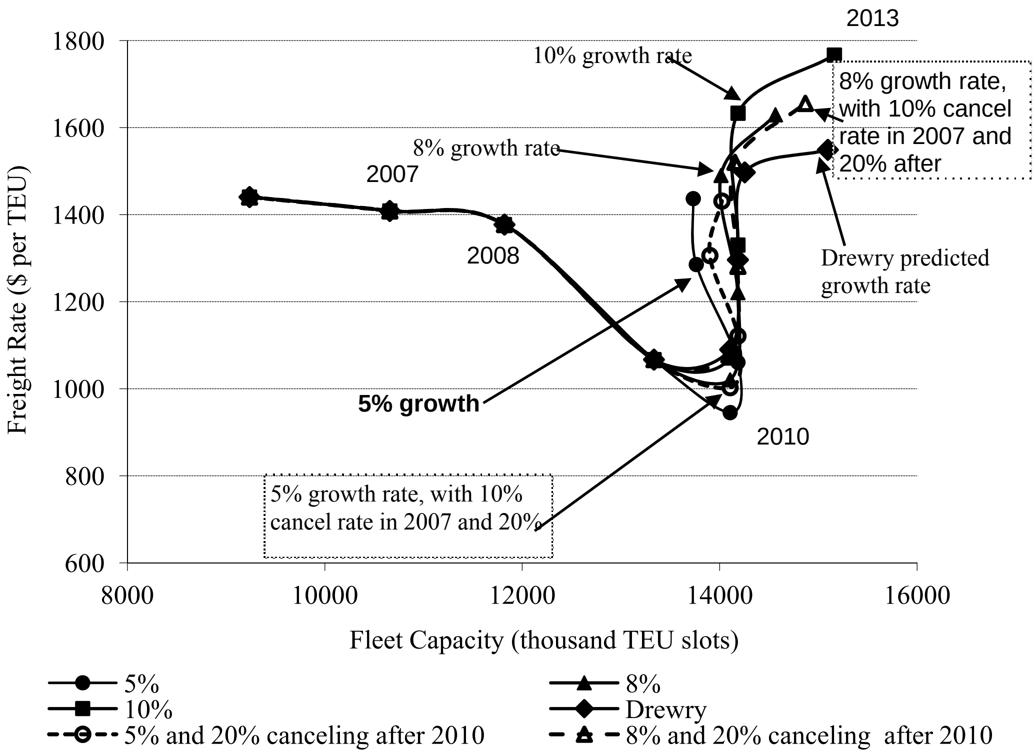
Drewry predicted growth rate (8.6%, 8.7%, 9.1%, 8.9%, and 8.7% from 2009 to 2013 respectively)

Figure 4-7 also includes the market prediction based on Drewry's forecast of the possible growth rate of the future container transportation demand.

According to this, the model shows that the freight rate will continue to decrease until 2010, then increase slowly until 2013. This reveals the excessive capacity in the world container fleet. The prediction base on the 10% growth rate is more optimistic than the Drewry figure, reflecting the best situation for a quick recovery. However, the high freight rate can encourage larger new orders, causing an earlier decreasing market in 2011. The prediction using 8% growth rate in future container throughput represents a more conservative prediction than Drewry's. The freight rate will be below US$1200 from 2010 to 2013, with a turning point after 2011. In this case, the new order activity will decrease, as the net profit decreases in the industry. Considering the current financial crisis and the low demand in container shipping, if the future demand increase rate is only 5%, then the freight rate will be below US$1100 in 2009, close to US$800 in 2010, and below US$800 in 2011.

Cancellations of new orders could slow down the decrease of the freight rate. For 8% future growth rate, if 10% of the new orders made in 2007 and 20% of new orders made afterwards are cancelled, the freight rate will stop decreasing in 2010 when it was slightly lower than US$1200, and it could be better than the predicated rate based on Drewry's prediction later. For a 5% growth rate, under the same cancellation scheme, the predicted freight rates are higher than those in the no cancellation case, and will never be below US$800. This shows that cancellations are beneficial to prevent a further drop in the freight rate, if the current financial crisis has a serious negative impact on the world economy and international trade. Because of the comparatively higher freight rate, when there is a cancellation, the new order will be higher than the case when there is no cancellation; therefore, the capacity with cancellation is larger than the capacity without cancellation.

Figure 4-8: Forecast of the container shipping market from model 80-09



The actual values in 2009 with the impact of the global financial crisis make the model prediction different, which is illustrated in Figure 4-8. Similar to the prediction from model 80-08, the model shows that the freight rate will continue to decrease until 2010, but could recover quickly, because the low ordering due to low industry profit (freight rate). This further leads to low capacity expansion in the market illustrated by the almost vertical or backward-bent lines after 2010.

4.6 Concluding remarks

This chapter presented a dynamic-economic model for the container shipping market characterized by the container shipping freight rate and the global container fleet capacity. The model postulates the changing of equilibrium freight rate under demand and supply shifts in the container shipping market. The world container fleet capacity is augmented by the number of new orders which is proportional to the industrial profit earned two years before. The quantity demanded of container transportation services, as a derived demand from international trade, is assumed to be exogenously determined in the model.

The model parameters were estimated using the global container shipping market data from 1980 to 2009, based on the available data from Drewry and Clarkson. Considering the interdependency of the two dynamic equations, a three-stage least square method was adopted in the regression analysis. The estimated results are quite stable, provided a high goodness of fit, and the parameter estimates are significant at above 90% confidence level. The overall model can explain more than 78% of the variations in fleet capacity and freight, and the in-sample prediction of the model can largely replicate the actual data within the research period.

As an application of the research, it predicted the future container market from 2009 (2010) to 2013, based on different assumptions of the future growth rate of container transportation demand. The result shows that if the world financial crisis continues to decrease the international trade, the container freight rate could drop to below US$1000 in 2010. With a decreasing rate of new orders and the cancellation of existing orders, the market freight rate could be saved from reaching such a low level, although the companies who cancel new orders will suffer some immediate losses. The purpose of this prediction is to alert the decision makers to the possible risks and short-term market trends in the container shipping sector.

In conclusion, the model can provide information for decision makers of both public policy and in private business. The maritime agencies or organizations at regional, national and international level can use this information to stabilize the market freight rate, so as to mitigate the negative impact of the recent financial crisis on the maritime industry, marine environment, maritime safety, and national, regional and local economies. In addition, bankers can use this information in ship financing decisions, to minimize the possible risks caused by the low freight rate. Finally, shipowners and ship operators can also use this method to setup their strategies to prevent or reduce possible losses in the coming years.

Chapter 5: Capacity expansion of liner companies

5.1 Introduction

The previous chapter analyzed the market adjustment principles using dynamic market analysis. As market supply is collectively determined by the investment decisions of individual shipping companies, this chapter moves forward to discuss the factors influencing individual liner companies' capacity expansion or capacity growth rate, which is also the fundamental element determining the concentration in liner shipping.

Concentration, which is collectively caused by each liner company's capacity expansion, means that relatively large shipping companies are increasing their market share at the expense of the remaining smaller players. As the industrial capacity and its concentration are determined collectively by the expansion behavior of individual shipping companies (Stopford, 2009), analyzing individual behavior in capacity expansion, especially of the large companies, is essential in understanding the economic factors that drive the industrial capacity changes and market concentration in the container liner market. Gibrat (1931) maintained that the company growth rate is independent of company size, which implies that both small companies and large companies have the same chance of growth. Scherer and Ross (1990) simulated the evolution of companies with the same initial size, and concluded that even under the Gibrat's law, the market could evolve into high concentration by purely chance factors. If economies of scale persist in the market, then large firms could possess an advantage that might result in more rapid growth. This would lead to even more rapid concentration in the market structure. Conversely, if small firms could by comparison grow faster, the tendency toward increasing company size inequality would be moderated, and market concentration could also be mitigated. Once a small company enters the large size bracket, the growth rate would fall. Thus, once a high level of concentration is achieved, there are forces tending to sustain it but not aggravate it.

Generally, there are two main types of capacity expansion: non-strategic and strategic. The former invests to replace old ships, meet increasing demand, or buffer possible demand shocks (Driver, 2000; Lieberman, 1987; Kamien & Schwartz, 1972). However, when the ship is getting bigger and future demand uncertain, non-strategic capacity expansion can often lead to excessive capacity in shipping (Fusillo, 2003; Le & Jones, 2005). The latter expands in order to improve market position in the competitive environment (Hay & Liu, 1998; Spance, 1979). Its purpose is to preclude the capacity expansion of competitors (Gilbert & Lieberman, 1987; Lieberman, 1987; Porter & Spence, 1982; Reynolds, 1986) or deter potential new entrants.

In the shipping industry, 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. Bendall and Stent (2005) assessed ship investment under uncertainty, using ROA (Real Option Analysis), in an express liner service. Wu (2009) formulated the optimal fleet capacity for a shipping company assuming cost minimization, and computed the optimal capacity for three carriers from 1992-2006. His findings suggest that the strategy of holding excess capacity and maintaining market power may have implicitly played a crucial role in determining the fleet capacity. However, there is no existing research on modeling the liner companies' capacity expansion behavior and analyzing the underlying factors affecting capacity expansion.

As a first step, the problem of market concentration that is caused by companies' capacity expansion is addressed by studying the growth rate of the liner companies.

5.2 Factors influencing liner companies' capacity expansion

Since the seminal work by Gibrat (1931), the topic concerning statistical properties of company dynamics and their size distributions has been investigated by a number of studies in applied industrial organization literature. The central idea of Gibrat's law is that company growth rate is independent of its size. This implies that the probability of a given change in size during a specified period is the same for all companies in a given industry, regardless of their size at the beginning of the period. Following Mansfield (1962), and Evans (1987a; 1987b), Gibrat's law can be illustrated by the equation (5-1):

$$K_{it} = U_i(t-1,t)K_{it-1}, \tag{5-1}$$

where K_{it} is the size of the ith company at time t, and $U_i(t\text{-}1,t)$ is a random variable distributed independently of K_{it}.

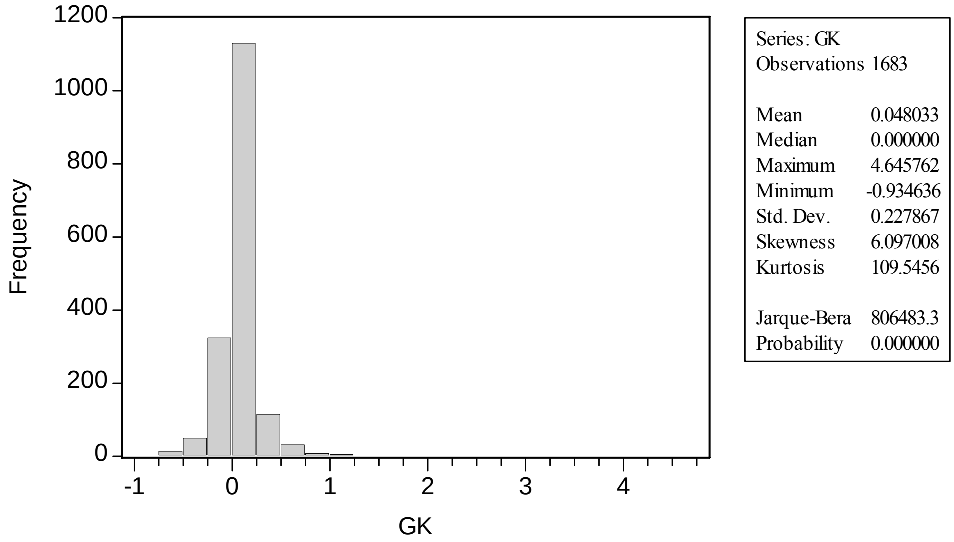
Dividing K_{it} on both sides of equation (5-1) and rearranging it, gets:

$$\frac{K_{it}}{K_{it-1}} - 1 = V_i(t-1,t) + W_i(t), \tag{5-2}$$

where $V_i(t\text{-}1,t)$ is the mean of $U_i(t\text{-}1,t)$ and $W_i(t)$ is a random variable with zero mean. The left-hand side of equation (5-2) is the annual growth rate of company size which can be explained as the size expansion of each company. If it is greater than 0, the company is expanding, otherwise, it is contracting. The absolute value of this term can present the magnitude of the expansion or contraction of the company.

However, by looking at the relationship between company size and growth over years in a panel of firms, a lot of researchers have rejected the Gibrat's law (Evans, 1987a; Evans, 1987b; Hart & Oulton, 1996; Mansfield, 1962; Sutton, 2002), that is, that the growth rate of a company is correlated to its size and other factors. This means that $V_i(t-1,t)$ may be affected by company scale and other factors. According to Gibrat's law, growth ought to be a random process. As such it should be drawn from a normal distribution with mean μ and variance σ^2 (Mata, 2008). Looking at the liner companies' distribution of growth rate (Figure 5-1), the null hypothesis of normal distribution is rejected by the Jarque-Bera test in this study. This provides some initial clues regarding the rejection of Gibrat's law in the container liner shipping industry.

Figure 5-1: Distribution of liner companies' growth rate



Next, the main factors that could impact a company's capacity expansion in the container liner shipping industry are identified, based on the former literatures and the operating practice in the market. There are two types of the such influencing factors, as indicated in $V_i(t-1,t)$. The first type relates to factors existing before the companies make their expansion decisions, such as company characteristics. The other type relates to factors existing at the time the companies make their expansion decisions, such as the market status.

5.2.1 Company properties

Factors concerning a company's characteristics may include:

5.2.1.1 Company scale

According to Gibrat's law (1931), the growth rate of a company is independent of its size. This implies that both large and small companies have an equal chance in capacity growth. As stated in section 5.2, a lot of researchers have rejected Gibrat's law. Among them, Evans (1987a; 1987b), Hart and Oulton (1996), and Sutton (2002) all found that a company's growth is negatively related to its size.

5.2.1.2 Charter market and chartering options

The existence of the charter market makes the situation more complicated as both investment and chartering can increase a company's operating capacity. Chartering ships is a popular operation in the shipping market (Williams, 1999), as it can divide the various costs, such as capital cost and management cost, and risks, between different parties (Gorton et al., 1999). The owners or financing institutions can avoid the duties of managing and operating the vessels, while the operators can enlarge their operating fleet without incurring financial problems (Gorton et al., 1999). According to Alphaliner (2010), most of the liner shipping companies in the world are used to chartering vessels from the charter market. Therefore, it is postulated that the existence or availability of the charter option may have some impact on the liner company's expansion decision.

It is necessary to take note that in the liner shipping market, bareboat chartering has become more common with changing trading and investment patterns (Gorton et al., 1999). The bareboat may often be described as a kind of ship financing rather than a genuine charter agreement, because the owner has surplus capital to invest, whereas the charterer, lacking such capital, has need for the vessel in his fleet. Under such a circumstance, carriers may just treat the chartered vessels as their own vessels. Therefore, chartered vessels, especially bareboat charters, may have no effect on liner companies' capacity expansion.

5.2.1.3 Size of ship

There are different types of ships in the container shipping market, ranging from less than 500 TEU (Feeder) to over 18,000 TEU (Post-Panamax). The smaller vessels are usually deployed in short-sea transportation, whereas most larger vessels are deployed on international trade routes. When companies are considering acquiring ships according to their company operation strategies, the size of the ships will definitely have an impact on their capacity growth rate. For example, companies focused on international services tend to acquire larger vessels when expanding their capacity. However, the high fixed cost and the large expanded slots may restrict the frequency of their expansion.

Other types of the factors affecting the market status may include:

5.2.2 Market status

5.2.2.1 Market demand

It is obvious that shipping companies are more likely to acquire vessels when the demand for transportation is high. This is also the most important factor that influences the generation of freight cycles in the shipping market (Stopford, 2009). According to Stopford (2009), in a booming market shipping companies rush to invest in ships. This collective investment behavior may result in over-capacity in shipping supply, because the new orders will not impact the market until the new ships are delivered. Conversely, when market demand is slack and there are too many ships, shipping companies stop ordering vessels, or even demolish some of their existing ships, which could help the freight market recover.

5.2.2.2 Market profitability

It is commonly believed that high market demand leads to high expansion. However, different to the market demand, market profitability or expectation of market profitability is also important (Luo et al., 2009). In an oversupplied market, the low freight rate suggests an unprofitable market and reduces the companies' expansion activity. Contrary to this, in an undersupplied market, the high freight rate suggests high profitability for the shipping market and motivates capacity expansion.

In the empirical analysis, the time charter rather than freight rate is chosen as an approximation of market profitability, since more detailed information about the time charter can be obtained from the CSIN database.

5.2.2.3 Investment cost or chartering cost

Similar to other industries, a common question arises: Does investment or chartering cost matter? As Merikas et al., (2008) analyzed, the "asset play" strategy-"buying low and selling high", is an important motive for acquiring ships in shipping. From the perspective of profit maximization, a liner company should expand less when the investment or chartering cost increases, all other things being equal. However, looking at the time charter rate together with newbuilding and second-hand prices in the container shipping market, it is seen that these three indices move in line with each other all the time. This may be because the container shipping market is a derived market from world trade, so the time charter rate and ship prices will be collectively determined by market supply and the exogenous market demand. Consequently, companies' capacity expansion may positively correlate with the investment or chartering costs.

5.2.2.4 Responses to other firms' expansion

In the container liner industry, each company may have different responses to other companies' expanding activity. The smaller companies may tend to follow the investment activity of others. However, restricted by their company scale and cash flow, the smaller companies' capacity growth rate may be lower than all the other companies. For larger companies, in order to keep market shares, they can expand more in response to all the other companies' capacity expansion.

5.2.3 Merger and acquisition (M&A) activities

In addition to the factors of companies' characteristics and market status, the integration activities of M&A have a great impact on companies' capacity expansion, as explained in the introduction. Omitting this variable, the estimation in the empirical model can be biased. Therefore, M&A activity is also included in the empirical analysis as an explanatory variable.

Summarizing from the Alphaliner database, the capacity growth rate for companies with M&A is about 44.8%, while it is only 3.58% for those observed without M&A. Table 5-1 illustrates the main M&A that are undertaken by the top operators in the liner market. Some companies use M&A as a strategy for market entry and growth. Some use it to pursue economies of scale, secure market power, or eliminate a competitor (Fusillo, 2009).

Table 5-1: Main M&A in the container liner market

Buyer	Taken-over company	Year	Buyer	Taken-over company	Year
Maersk Line	Safmarine CMB-T Sealand	1999	Hamburg Sud	Barbican Line Transroll South Pacific Crowley	1999
	Torm Lines	2002		Crowley American Transport	2000
	Royal P&O Nedlloyd	2004		Ellermen	2002
	P&O Nedlloyd	2005		Kien Hung Lines	2003
CMA-CGM	United Baltic Corp. MacAndrews & Ellerman Iberian Delom SA	2002		Columbus Line	2004
	ANL Container Lines	2003		FESCO Ybarra Sud	2006
	OTAL Sudcargos	2005		Costa Container Lines	2007
	Delmas	2006	Delmas	OT Africa Line	1999
	US Lines Cheng Lie Navigation Ltd. CoMaNav	2007	PIL	Pacific Direct Line	2006
Evergreen Line	Hatsu Marine Ltd.	2002	Wan Hai	Interasia	2002
Hapag Lloyd	CP Ships	2005		Trans-Pacific Lines	2005
CSCL	Shanghai Puhai Shipping Company	2005	Grimald	ACL	2002
Hanjin	DSR-Senator	2002		Finnlines	2005
MOL	P&O Neddlloyd	2005	Sea Consortium	Sea Med Link	1999
P&O Nedlloyd	Tasman Express Line	1999	Odiel Group	Compania Transatlantica Espanola	2000
	Farrel Line Harrison Line	2000	CP Ships	TMM CCAL	2000
CSAV	Libra Grupo Libra Montemar	1999		Italian Line	2002
	Norasia	2000	TMM	Tecomar	1999
	Norsul container activities	2002	Wallenius	Wilhelmson	1999
The Rickmers Group	Rickmers Lines	1999	Tropical Shipping	Kent Lines	2001
TecMarine	Seaboard	2003		Tecmarine	2002

Sources: Compiled from Midoro et al. (2005), Fusillo (2009), Sys (2009), and Alphaliner (2010).

5.3 Description of the data and variables

Using Alphaliner and Clarkson's database together with Drewry's annual report, the following variables are calculated. Table 5-2 provides a summary of statistics for all the variables used in the model.

Table 5-2: Descriptive statistics

Variable	Unit	Observation	Mean	Std.Dev.	Min	Max
GK		1683	0.048	0.228	-0.935	4.646
SHARE		1683	0.006	0.015	0.0004	0.168
CHSHARE		1530	-0.045	0.214	-0.935	4.131
CHARTR		1683	0.510	0.334	0.000	1.000
AVGK	Thousand TEU	1683	1.118	0.773	0.188	4.27
THROU	Million TEU	1683	0.362	0.107	0.209	0.525
GTHROU		1683	0.090	0.065	-0.094	0.143
TC[a]		1683	0.899	0.321	0.354	1.519
NBP[b]		1683	0.945	0.192	0.710	1.240
SEP[c]		1683	0.869	0.302	0.490	1.370
OEX		1683	0.097	0.038	-0.009	0.199
INR		1683	0.455	0.498	0	1
MERGER		1683	0.030	0.170	0	1

Note: a, b, c, and d are all from Clarkson Research Services Limited (2010).
[a] Containership Time Charter Rate Index: Based on $/TEU for 1993 = 1.
[b] Containership New-building Price Index: Based on average $/TEU for Jan 1988 = 1.
[c] Containership Second-hand Price Index: Based on average $/TEU for Jan 1988 = 1.

The dependent variable, *GK*, is the capacity growth rate of a liner company for each year, which is calculated as $GK_{it} = \frac{K_{it}}{K_{i,t-1}} - 1$, where K is the total controlling capacity of each company.

As analyzed in section 5.2, the following variables are used to test the companies' specific characteristics influencing container liner companies' decisions before their capacity expansion in year t-1.

SHARE is the share of a company's controlled capacity (includes vessels both owned and charted by the company) in the 153 liner companies in a year, defined as $SHARE_{it-1}=K_{it-1}/\Sigma_i K_{it-1}$.

CHSHARE is the annual change of market share for each company, which is defined as $CHSHARE_{it-1}=SHARE_{it-1}/SHARE_{it-2}-1$.

CHARTR is the ratio of the chartering capacity from the charter market to the actual controlling capacity. It is defined as $CHARTR_{it-1} = \frac{CK_{it-1}}{K_{it-1}}$, where *CK* is the chartering capacity for each company.

AVGK is the average vessel size of each company, which is defined as the total controlling capacity divided by the number of vessels of the company (*NK*), $AVGK_{it-1} = \frac{K_{it-1}}{NK_{it-1}}$.

Following are the variables used to test the other types of influencing factors concerning market status.

THROU and *GTHROU* are two variables used to examine how demand changes the capacity expansion behavior. The former is the global container throughput, and the latter is its annual growth rate, which is defined as $GTHROU_t = \frac{THROU_t}{THROU_{t-1}} - 1$.

TC and *GTC* are the annual time charter index and growth rates of time charter index for container ships.

NBP and *SEP* are the annual newbuilding price index and second-hand price index. In the shipping market, companies can expand capacity by ordering newbuildings, buying second-hand vessels, or chartering in vessels. Because these three variables are highly correlated, only *NBP* is used as an index of investment costs or chartering costs in capacity expansion in the empirical analysis.

OEX is the capacity expansion of the competitors for each company, 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 response of a company to all other companies' capacity expansion activities. Compared with the variable *CHSHARE*, which takes into account its own and other companies' expansion, *OEX* captures only the influence of all the other companies' capacity expansion.

INR is a dummy variable representing the market status. It is 1 if the time charter rate is increased in a year, and 0 otherwise. The value of 1 suggests that the profitability of the liner market is increasing, while the value of 0 suggests that the market profitability is decreasing.

To analyze the impact of integration on liner companies' capacity expansion, companies' M&A activities are also included in the empirical analysis as a control variable (Table 5-1). Variable *MERGER* is a dummy variable indicating the M&A for each company in a certain year.

Finally, companies of different size may respond to the market demand and capacity expansion of other companies differently. To detect this behavior, interaction terms between the capacity share of each firm (*SHARE*) and some other independent variables are created, including *CHSHARE*, *THROU*, *GTHROU*, *OEX*, and *MERGER*.

5.4 Empirical results and discussion

5.4.1 Hausman's specification test

Table 5-3 summarizes the results of four different models of capacity expansion behavior. Models (1) and (2) are the fixed effect models. Model (1) includes all the variables identified in Section 2, except for the control variable *MERGER*. Model (2) includes all the variables and the interactive between *SHARE* and *CHSHARE*, *THROU*, *GTHROU*, *OEX*, and *MERGER*. Models (3) and (4) are the random effect models corresponding to models (1) and (2).

Using the F test in Equation 3-40, the null hypothesis that the constant terms are all equal 0 or that there is no group effect in the data can be calculated for models (1) and (2) respectively. The corresponding statistics are $F(152, 1362)=2.14$ and $F(152, 1360)=1.96$. Both of them are higher than the critical value of 1.31 at 99% significance level. Therefore, the null hypothesis is rejected, which means that there exist individual effects in the company expansion data.

Similar to the F test, the null hypothesis of no variance across companies in the random effect models (3) and (4) can be tested using the LM test specified in Equation 3-45. Using the error terms obtained from models (3) and (4), the statistics are LM=0.43 and 0.17 respectively. Both of them are lower than the critical value of 3.84 at 95% significance level, hence the null hypothesis is not rejected. This means that there are no individual variances among the liner companies.

The above tests seem to support the adoption of the fixed effect model. To further identify the appropriateness of the fixed effect model, the Hausman's specification test is calculated based on the results from models (1) and (3), and (2) and (4). Using Equation 3-46, the statistics of $W = \chi^2[k] = [b - \hat{\beta}]'[Var(b) - Var(\hat{\beta})]^{-1}[b - \hat{\beta}]$ are 40.62 and 122.64 respectively. Both of them are larger than the critical value of 30.58 and 33.41 with 15 and 17 degrees of freedom. The hypothesis that the individual effects are uncorrelated with the other regressors can be rejected. Based on the *F* test that there are individual effects, and the Hausman's test, which suggests that these effects are correlated with the other independent variables in the model, it can be concluded that for the two alternatives considered, the fixed effect model is the better choice.

5.4.2 Results and discussion

Judging from the results in Table 5-3, most of the coefficients are significant, and the high significance of the *F*-test or Wald Chi2-test suggests the fitness of the model. As analyzed above, the following explanation is based on the result from model (2).

Table 5-3: Regression results for capacity expansion models

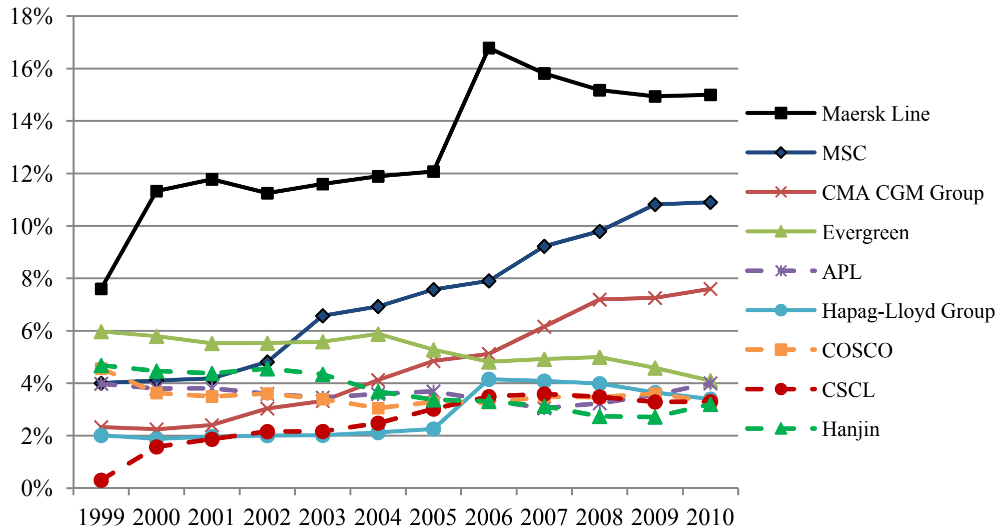
VARIABLES	(1) Fixed Effect GK	(2) Fixed Effect GK	(3) Random Effect GK	(4) Random Effect GK
SHARE	-31.250***	-31.863***	-12.654***	-12.372***
	(2.739)	(2.798)	(1.766)	(1.692)
CHSHARE	-0.217***	-0.184***	-0.140***	-0.131***
	(0.031)	(0.030)	(0.032)	(0.030)
SHARE×CHSHARE	7.340***	6.565***	5.225**	5.065**
	(2.208)	(2.156)	(2.167)	(2.078)
CHARTR	-0.061*	-0.067**	-0.002	-0.008
	(0.035)	(0.034)	(0.017)	(0.016)
AVGK	-0.148***	-0.133***	0.017*	0.008
	(0.025)	(0.024)	(0.009)	(0.009)
THROU	-0.301	-0.282	-0.600**	-0.499*
	(0.271)	(0.259)	(0.284)	(0.270)
GTHROU	-0.133	-0.230	-0.280	-0.338
	(0.250)	(0.240)	(0.263)	(0.250)
SHARE×THROU	28.164***	32.867***	14.353***	18.421***
	(5.020)	(4.874)	(4.809)	(4.635)
SHARE×GTHROU	-4.740	1.070	15.363***	16.368***
	(5.743)	(5.785)	(5.668)	(5.835)
TC	-0.154**	-0.139*	-0.247***	-0.212***
	(0.075)	(0.072)	(0.079)	(0.075)
GTC	0.090*	0.098**	0.100*	0.105**
	(0.049)	(0.047)	(0.052)	(0.049)
NBP	0.344	0.317	0.631***	0.544**
	(0.228)	(0.218)	(0.239)	(0.227)
OEX	-0.856**	-0.759**	-1.379***	-1.158***
	(0.370)	(0.354)	(0.388)	(0.369)
SHARE×OEX	57.842***	47.485**	59.208***	40.440**
	(19.750)	(18.965)	(20.474)	(19.462)
OEX×INR	-0.359	-0.353*	-0.513**	-0.475**
	(0.222)	(0.212)	(0.234)	(0.222)
MERGER		0.553***		0.554***
		(0.049)		(0.043)
SHARE×MERGER		-7.323***		-5.536***
		(1.188)		(1.051)
Constant	0.380***	0.359***	0.069*	0.065*
	(0.047)	(0.045)	(0.037)	(0.035)
Observations	1,530	1,530	1,530	1,530
Number of owners	153	153	153	153
F/Wald Chi2	16.37	23.50	127.7	315.0
Porb(F/Chi-test)	0.000	0.000	0.000	0.000

Note: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

The market share variable is highly significant throughout models (1) to (4). The negative coefficient for *SHARE* suggests that the capacity expansion rate of the larger companies is lower than that of smaller ones. This echoes former researchers' rejection of Gibrat's law that a company's growth rate is independent of its size (Mansfield, 1962; Evans, 1987a; Evans, 1987b; Hart & Oulton, 1996; Sutton, 2002; Fan et al., 2011).

The negative coefficient for *CHSHARE* indicates that the expansion rate decreases with the increase of the company's market share. However, larger companies appear differently from the smaller ones when responding to market share change, as indicated by the coefficient of *SHARE*×*CHSHARE*. Thus, the data shows that for larger companies (capacity share greater than 2.803%=0.184/6.565), capacity expansion is positively correlated with recent changes in market share, which suggests that increases in market share are followed by more expansion, although the net increasing rate for larger firms is still lower than for smaller ones. This result is consistent with the fact that most of the larger liners had constantly increasing or decreasing market share during the study period (see Figure 5-2, from the Alphaliner database). This clearly shows a trend of concentration among the major liner companies: some have a continuously increasing capacity share, while others have constant decreasing market share in the past decade. Among the major top 10 LSCs, Maersk, MSC and CMA CGM Group have experienced fast market share increase from 1999 to 2010, and have emerged as the top 3 liners that accounted for around 34% of the world container capacity.

Figure 5-2: Annual evolution of market share for the main carriers



Source: Alphaliner (2010).

The negative coefficient for *CHARTR* reflects the differences in capacity expansion for those liner companies with different ship-owning policies. Most of the liner companies maintain a relatively stable charter ratio. For example, according to the Alphaliner database, the charter ratio for Maersk is around 45 per cent, and that for MSC is 40 per cent. Chipolbrok's vessels are all owned by itself and Sea Consortium's vessels are all charted from the market. This result indicates that different companies may have different strategies in operating and managing their vessels, which has a significant influence on their capacity expansion rate.

The coefficient for *AVGK* is negative and significant, which suggests that average ship size has a negative impact on a company's capacity expansion. This may be because of the higher fixed costs induced by the larger vessels. Therefore, the growth rate of liner companies with a larger average ship size is lower. Although the coefficient estimates on *THROU* and *GTHROU* are not significant, the interactive variable between *SHARE* and *THROU* is positively significant. This indicates the positive influence of demand on the capacity expansion of larger liner companies. When demand increases, larger companies can expand their capacity quickly, as they may have more revenue or cash flow to support the expansion.

The coefficient on *TC* is negative, while the coefficient on *GTC* is positively significant. As TC is used as a proxy for freight rate because they are highly correlated, this suggests that liner companies will expand in a rising market, but not when the freight rate is high. It may suggest the caution of the liner companies in expanding capacity. There is crowded capacity expansion at high market prices or profitability, which may drive down the price. Rational companies will expand or invest in vessels when they see the market profitability increasing.

The coefficient on *NBP* is not significant, which may be because the liner shipping market is a derived market, and capacity acquiring cost is not as direct a factor in companies' capacity expansion as market demand and profitability. This agrees with Luo et al., (2009) that liner companies do not acquire more ships just because its price is low. It is because the demand for transportation services is high, which is also the time when prices for ship chartering, newbuilding and second-hand vessels are also high.

The coefficients on *OEX*, *OEX*×*INR*, and *SHARE*×*OEX* are also significant, indicating the response of the container liner company to the capacity expansion of all the other companies. The negative coefficients on the first two variables indicate that shipping companies are trying to avoid expanding at the same time as others, especially when the freight rate is increasing. This result implies that there may be some rationality in capacity investment in the container liner shipping industry. However, a different picture emerges when interaction effects with market share are considered. The net marginal effect of other companies' capacity expansion (*OEX*) for the larger companies (capacity share greater than 1.598%=0.759/47.485) is positive, while it is negative for the smaller ones (smaller than 1.598%). This suggests that the larger companies pay more attention to other companies' capacity expansion activities, and will respond to them more aggressively by further expansion. Carriers in the top 20 list have capacity share higher than this number. This suggests that the top 20 carriers are more sensitive to the aggregated expansion of all other companies. Smaller companies are less sensitive, may be because their market share is too small. Such capacity expansion strategy of larger liners can lead to over capacity and further concentration in the industry.

Finally, the significant coefficient on dummy variable *MERGER* is positive, which suggests a high capacity expansion resulting from companies' M&A. It reveals that, on average, M&A will significantly enlarge the capacity increase rate. The negative coefficient on the interaction between *SHARE* and *MERGER* indicates that for larger companies, the impact on capacity increases is much lower compared to the smaller ones, as the base capacity for a larger company is higher. If a company's capacity share is larger than 7.55% (=0.553/7.323), such impact can even be negative. At present, only the 3 biggest companies, namely Maersk, MSC, and CMA CGM Group, have capacity share larger than 7.55%. While the M&A for smaller firms can result in efficiency improvement due to economy of scale, for larger firms, such as the carriers in the top 10 list, it may speed up the concentration process. Therefore, it is necessary to differentiate the M&A for liners with different scales.

To summarize, the negative relationship between company market share and the capacity expansion rate indicates that larger companies grow at a lower speed than smaller ones. The empirical estimate reveals that market demand and market profitability, rather than the capacity acquiring cost, are important factors that drive the liner companies' capacity expansion. In addition, this chapter reveals distinct differences between liner companies of different sizes. Most of the larger liners have a constantly increasing or decreasing market share during the data period. Furthermore, in responding to the aggregated capacity expansion of all other carriers, larger companies tend to increase faster than smaller ones. Finally, the result highlights the important role that company integration activity through M&A plays on company capacity expansion. Therefore, to control the process of market concentration, the most effective way would be to show more concern over the integration activity of M&A.

5.5 Concluding remarks

This chapter identified and tested some of the major factors determining capacity expansion behavior in the liner shipping industry, using empirical analysis by panel data methods. The empirical analysis used actual existing shipping company expansion data, referencing 153 containership operators over the period 1999-2009.

Result from the model suggests that the larger companies' capacity expansion is lower than that of the smaller ones, which is in rejection of Gibrat's law of the independence of company growth and company size. When companies make capacity expansion decisions, they consider both the operational needs to supply the market demand, and the strategies for market competition. The positive and significant impact on capacity expansion from demand and market profitability reveals their expansion behavior in meeting the operational requirements. Furthermore, companies of different sizes have different responses to demand, although they are both inclined to expand more when demand is increasing. Larger companies tend to be more responsive to demand than smaller ones, as they may have more revenue or cash flow that enables them to expand in order to accommodate the high demand.

Companies' capacity expansion behavior when facing market competition includes their responses to the change of market share, and to competitors' capacity expansion. The result reveals that for large carriers, expansion rates are found to be in line with market share changes: firms with expanding market share increase faster, while those with shrinking market share have a lower rate. This indicates the possibility of further concentration by expanding firms. The response to other companies' capacity expansion reveals a shipping company's competitive capacity expansion behavior with respect to the actual capacity change of the other companies. There is serious competition among the container liner shipping industry, especially for the larger ones. A company will refrain from expanding more while all the others are still making plans to expand, especially when the market freight rate is increasing. However, for larger companies, the aggregated investment of the others will cause it to increase its expansion so as to avoid any loss of market share.

As the main contributor to capacity concentration in the liner market, M&A have a great impact on liner companies' capacity expansion, which could change the companies' expansion behavior. An effective way to control the process of market concentration would be to have more concern about the integration activity of M&A.

Chapter 6: Ship investment decisions

6.1 Introduction

Chapter 5 discussed the determinants for the capacity expansion rate of individual liner shipping companies. This chapter moves on to study one of the common ways in capacity expansion for the companies, decisions in vessel investment. Comparing with the numerous studies on shipping market analysis, there are only a few publications on analysing ship investment decisions. Jansson and Shneerson (1982) studied optimal ship size by minimizing the unit cost at sea and in port, for different route characteristics (distance, handling rate, and cargo balance) and fuel price. The study reported that liners select a ship according to the intended route of deployment. Fusillo (2003) modelled the investment of excess capacity and tested whether shipping companies used excessive capacity to defend opportunistic rivals, and found that existing statistics show limited support to the entry-deterrence postulation. Bendall and Stent (2005) studied ship investment under uncertainty, using ROA (Real Option Analysis) to value the flexibility in introducing an express liner service. The study demonstrated the use of ROA to explain the capacity management behavior that is seemingly suboptimal in classical Net Present Value analyses. Alizadeh and Nomikos (2007) applied a cointegration approach for investment timing and divestment decisions in shipping markets. Merikas, Merika & Koutroubousis (2008) tested the cointegration between the ratio of second-hand price with the new building price and main market factors including time charter rate, second-hand volume, crude oil price, shipbuilding cost, freight volatility, and ship financing rate. They found the relative preferences of ship operators for second-hand ships (5 years old) over new ships at different shipping cycles. When the freight rate is increasing, shipping companies prefer second-hand ships because they can be deployed right away. When the freight rate is decreasing, liners are eager to get rid of the excessive capacity. Although the study fails to quantify the impact of freight rate on the new and second-hand ships, it serves as a clear reference for studying ship selection behavior.

There has been little empirical research on ship investment and selection behavior for liner shipping companies. For them, when to purchase their own ships and how to select a ship are two critical decisions for the development and operation of the company, yet they are difficult issues to address because of the complexity of the shipping industry. To address these issues, this chapter and the next chapter attempt to explore important factors in ship investment through analysing the actual ship purchasing decisions of the top 100 liners in the world in each year which includes totally 153 companies. The results will not only provide support for ship investment decisions of individual shipping companies, and the public agencies responsible for regulating shipping capacity, but will also direct future research on shipping investment analysis.

6.2 Theoretical analysis of investment decision

Ships are expensive assets in the maritime transportation especially in the container shipping market. From the perspective of the liner shipping company, the basic investment decision is whether they invest at certain market conditions, be it to satisfy the market needs or to compete with the peers.

Assume that there is no strategic behavior 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 company can increase the speed of the ship, reduce port time, shorter ballast legs, or delay regular maintenance to satisfy the demand in the short-run (Beenstock & Vergottis, 1993; Koopmans, 1939). However, sailing fast is costly, and there is 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 these factors on the ship investment decision, it is started from a very simple case where the company is running a fixed service between two ports.

6.2.1 Basic operation mechanism for a shipping fleet

Assume the shipping company controls N identical container vessels of K TEU slots and it uses n vessels in transportation activity where n_1 ships are owned by the company and $n2$ ships are charted from the market. For each owned vessel, the operation cost is C_1. For each charted vessel, the operation cost is C_2. 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 $s\rho / L$. Finally, the demand the shipping company facing is Q and the market freight rate is P.

From above assumptions, the problem for the shipping company is to maximize its annual profit with respect to the number of ships the liner company owns n_1 ($n \leq N$) and ship speed s, that is,

$$\max_{n,s} \pi = Pq - n_1 C_1 - n_2 C_2 - n\frac{s\rho}{L}V(s) - (N-n)LC \qquad (6\text{-}1)$$

$$s.t.\; q = n\frac{s\rho}{L}K \leq Q, n = n_1 + n_2 \leq N, and\; s \leq \bar{s}.$$

where $\bar{s}$ is the speed limit of ships. Solving this problem using Karush-Kuhn-Tucker method, four different cases can be obtained:

$$\begin{aligned} &n = N, q = n\tfrac{s\rho}{L}K = Q, s \leq \bar{s}. \text{ (a)} \\ &n = N, q = n\tfrac{s\rho}{L}K < Q, s \leq \bar{s}. \text{ (b)} \\ &n < N, q = n\tfrac{s\rho}{L}K = Q, s \leq \bar{s}. \text{ (c)} \\ &n < N, q = n\tfrac{s\rho}{L}K < Q, s \leq \bar{s}. \text{ (d)} \end{aligned} \qquad (6\text{-}2)$$

Under case 6-2c and 6-2d, the shipping company's existing fleet are not fully utilized. In these cases, the company will not have incentive to acquire additional vessels.

Case 6-2a and 6-2b describe the situations when a shipping company may have incentive to purchase additional ships. In case 6-2a, the optimal speed is $s^* = \min(Q\frac{L}{N\rho K}, \bar{s})$. If the optimal speed is lower than the technical limit, the shipping company can increase vessel speed to accommodate the increasing demand. However, if the voyage cost is too high for sailing at high speed, the shipping company will have incentive to purchase or charter-in more ships, as long as the savings from the reduced speed can offset the incremental capital and financial cost, operation cost and voyage cost. In case 6-2b, the optimal speed is $s^* = \min(s_o, \bar{s})$. s_o is determined when the freight rate is equal to the marginal cost of shipping speed, i.e, $P = \frac{V(s_o) + s_o V'(s_o)}{K}$ (see Appendix). If the freight rate is lower than the marginal cost, even though there is unsatisfied demand, it is not profitable to carry them by increasing the speed. In this case, the shipping companies may have incentive to purchase another ship if the earning for shipping addition cargo with one more vessel and possible savings using slower speed can offset its associated capital and operation cost. Next, the condition for purchasing additional ships is analyzed.

6.2.2 Factor analysis for ship investment

Under case 6-2a, when the optimal speed is lower than the vessel speed limit, facing a demand increase from Q to $\overline{Q}$, given the number of ships charted n_2, the shipping company can increase vessel speed to $s_N = \overline{Q}\frac{L}{N\rho K} \leq \bar{s}$. At this speed, the operating cost will increase to $V(s_N)$. However, with additional vessel, the optimal speed could decrease to $s_I = \overline{Q}\dfrac{L}{(N+1)\rho K} < s_N$. Assuming that the ship cost is CK and the loan rate is d, if the annual incremental profit with one more ship can offset its additional annual capital cost, that is, $\pi(N+1) - \pi(N) - dCK \geq 0$, the shipping company is better to buy the additional vessel. Use y_a to denote the net benefit with or without additional ship. Through a series of simplification process, y_a can be written as:

$$y_a = \frac{\overline{Q}}{K}[V(\bar{s}) - V(\bar{s}_I)] - C_1 - dCK \tag{6-3}$$

Under case 6-2a, when the optimal speed is $\bar{s}$, or under case 6-2b, the optimal vessel speed is fixed at certain freight rate s_o or at $\bar{s}$, with an additional ship, the liner company's revenue will increase to $\pi(N+1)$. Then if the incremental profit with additional ship is larger than the additional capital and financial cost, the company is better to buy the additional vessel. The net benefit of investment can be simplified as:

$$\begin{aligned}
y_b &= \pi(N+1) - \pi(N) - dCK \\
&= P(N+1)\frac{s\rho}{L}K - (n_1+1)C_1 - n_2C_2 - (N+1)\frac{s\rho}{L}V(s) \\
&\quad - PN\frac{s\rho}{L}K - n_1C_1 - n_2C_2 - N\frac{s\rho}{L}V(s) - dCK \\
&= P\frac{s\rho}{L}K - C_1 - \frac{s\rho}{L}V(s) - dCK \\
&= \frac{s\rho}{L}(PK - V(s)) - C_1 - dCK
\end{aligned} \tag{6-4}$$

In theory, when y (y_a or y_b) >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 or growth of demand and freight rate; decreases with operating cost and ship price. The average ship capacity, total number of vessels N, demand and freight rate is affecting the net benefits through optimal shipping speed.

In summary, the investment decision of individual 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,

$$Y_{it} = y_{it} + \varepsilon_{it} \tag{6-5}$$

where $y_{it}=f(Q_t, GQ_t, P_t, K_{it}, CK_{it}, n_{i1}, n_{i2})=x_{it}'\beta + \varepsilon_{it}$, and Y_{it} takes value 1 if invest, 0 if not:

$$Y_{it} = 1\ invest, if\ y_{it} > 0,$$

$$Y_{it} = 0\ not\ invest, if\ y_{it} \leq 0. \tag{6-6}$$

Assuming that ε_{it} is independently and identically distributed (iid) with logistic distribution, the liner company's capacity investment decision can be modelled using a binary choice logit model (Greene, 2003).

6.3 Description of the data and variables

Using the combined database from Alphaliner, Clarkson, and Drewry, the investment decision is explained using panel data of each company from 1999 to 2009. Table 6-1 provides a summary statistics for all the variables used in the investment decision. The meaning of each variable is introduced below.

Table 6-1: Descriptive statistics for data used in the investment decision model

Variable	Unit	OBS	Mean	Std. Dev.	Minimum	Maximum
INVEST		1683	0.2305	0.4213	0.0000	1.0000
THROU	Million TEU	1683	362.4534	107.3593	209.0740	525.2850
GTHROU		1683	8.9581	6.4906	-9.3658	14.3135
CHARTR		1683	0.5114	0.3366	0.0000	1.0000
K	Thousand TEU	1683	54.3071	146.1077	4.5170	2029.1420
SHARE		1683	0.6413	1.5122	0.0333	16.7861
CHSHARE		1683	-4.4263	20.8467	-93.5358	413.1278
AVGK	Thousand TEU	1683	1.1464	0.8100	0.1879	4.3695
TCMI[a]		1683	90.3721	32.8161	32.0000	171.8400
GTCMI[a]		1683	-0.0217	0.2934	-0.6158	0.5418
NBPMI[b]		1683	94.2985	19.3772	71.0000	128.0000
SEPMI[c]		1683	87.4674	31.2986	47.0000	161.0000

Note: a, b, c, and d are all form Clarkson Research Services Limited (2010).
[a] Containership Time Charter Rate Index: based on $/TEU for 1993 = 100.
[b] Containership Newbuilding Prices Index: based on average $/TEU for Jan 1988 = 100.
[c] Containership Second-hand Prices Index: based on average $/TEU for Jan 1988 = 100.

INVEST is the binary dependent variable representing the investment decision of a liner company at each year. If the company ordered a new ship or bought a second-hand vessel, the value is 1; otherwise, it is 0.

THROU and *GTHROU* are the global annual container throughput and a hundredfold of the growth rate of throughput (($THROU_{it}/THROU_{it-1}$-1) ×100) at the time of investment. These two variables are used to link the investment decision with demand and demand change.

K is the total controlling capacity of a company at the beginning of a year, which includes both owned and chartered capacity.

SHARE is a hundredfold of the share of a company's capacity in all the capacity controlled by the 153 liner companies in a year. It is calculated using $(K_{it}/\Sigma K_{it})*100$.

CHSHARE is a hundredfold of the market share change rate for a company, which is defined as $CHSHARE_{it}=(SHARE_{it}/SHARE_{it-1} -1)*100$.

CHARTR is the ratio of the chartered capacity in the controlled capacity of a company. It is used to test the linkage between the chartered ratio and the investment decision.

AVGK is the average vessel size of a company, defined as the total controlling capacity divided by the number of vessels of the company. This gives an indication on the route division of the company (ships in the East-west route are larger than those in the South-north trade).

TCMI is the time charter index for container ships. It is used as an approximation to freight rate for two reasons. First, detailed container freight rate are not available and therefore the monthly data on containership time charter rate from the CSIN database is used. It is recognized that the time charter rate and container freight rate are two different concepts. However, they are highly correlated. The correlation coefficient between these two variables is 0.71.

Second, time charter rate is a better indicator for future shipping than spot rate (Haralambides et al., 2005). It reflects the expectation of future market profitability, while freight rate represents the past market performance. In this analysis, if a company ordered a new ship or purchased a second-hand one, *TCMI* is the monthly average time charter rate. If a company did not invest, it is the annual time charter rate. *NBPMI* and *SEPMI* are newbuilding price index and second-hand price index respectively, constructed in the same way.

6.4 Empirical results and discussion

Four different models are applied to analyze the impacts of different variables on the ship investment decision of liners. The estimation results are shown in Table 6-3. Model 1 includes all the variables introduced in section 6.2. Model 2 adds *CHSHARE* − the change of the market share. Model 3 adds the interaction between *SHARE* and *CHSHARE*, to explore the different investment strategies between larger and smaller companies in response to the market share change. Model 4 omits the insignificant variable *AVGK*. The last column includes the marginal effects of each variable based on the results from model 4. Because the monthly price index for newbuilding and second-hand vessels are highly correlated, only *NBPMI* is used in these models.

Table 6-2: Results from binary choice models for ship investment decisions

VARIABLES	(1) INVEST	(2) INVEST	(3) INVEST	(4) INVEST	Marginal Effect for (4)
THROU	0.005***	0.005***	0.005***	0.005***	0.001
	(0.002)	(0.002)	(0.002)	(0.002)	
GTHROU	0.063***	0.062***	0.062***	0.063***	0.010
	(0.017)	(0.017)	(0.017)	(0.017)	
CHARTR	-0.820***	-0.844***	-0.841***	-0.838***	-0.136
	(0.190)	(0.191)	(0.192)	(0.191)	
SHARE	0.433***	0.412***	0.450***	0.466***	0.075
	(0.071)	(0.071)	(0.074)	(0.052)	
CHSHARE		0.009***	0.012***	0.012***	0.002
		(0.003)	(0.004)	(0.004)	
SHARE×CHSHARE			-0.005*	-0.005*	-0.001
			(0.003)	(0.003)	
AVGK	0.071	0.066	0.032		
	(0.103)	(0.103)	(0.105)		
NBPMI	-0.044***	-0.042***	-0.042***	-0.042***	-0.007
	(0.012)	(0.012)	(0.012)	(0.012)	
TCMI	0.024***	0.023***	0.023***	0.023***	0.004
	(0.004)	(0.004)	(0.004)	(0.004)	
CONSTANT	-1.800***	-1.812***	-1.798***	-1.777***	
	(0.392)	(0.393)	(0.394)	(0.388)	
Observations	1,683	1,683	1,683	1,683	
logL	-795.5	-791.3	-789.9	-790.0	
Chi-Square	226.4	234.8	237.5	237.4	
Prob>Chi2	0	0	0	0	
Pseudo R-squared	0.125	0.129	0.131	0.131	

Note: Standard errors in parentheses. * Significant at the 0.1 level; ** Significant at the 0.05 level; ***Significant at the 0.01 level; two-tailed test.

In the first three models, one common property is that the estimated coefficients on *AVGK* are not significant. This suggests that the average capacity of a shipping company has no significant statistical relationship with its investment decision. Except for *AVGK*, the estimated results for all other variables are very similar in the four models. The following explanations are based on the results from model 4.

All the estimated coefficients are significant, demonstrating the robustness of the model. The estimated coefficients on *THROU* and *GTHROU* are positive, indicating positive impacts of high market demand and high demand increasing rate on the investment decision. The marginal effect of throughput shows that for a one million TEU increase in demand, the probability of investment will increase by 0.1 per cent. In addition, one per cent increase in the demand-increasing rate will increase the probability of investment by 1 per cent.

The negative coefficient for *CHARTR* reflects the ship-owning policy of a liner: If a company has the tradition to charter more, it will invest less on its own ships. Most of the liner companies keep a relatively stable charter ratio. For example, from the Alphaliner database, it was found that the charter ratio for Maersk is around 45 per cent, and that for MSC is 40 per cent. Chipolbrok's vessels are all owned by itself and Sea Consortium's vessels are all charted from the market.

The positive coefficients for *SHARE* and *CHSHARE* indicate that companies with a large capacity or a large market share change are more likely to invest. However, large companies appear differently from the smaller ones when responding to market share change, as indicated by the coefficient of *SHARE*×*CHSHARE*. For given market share change, if the market share of a company is larger than 2 per cent, the net marginal effect for that company will be negative (2×(-0.001)+0.002=0). This implies that small companies (*SHARE*<2) are either grew aggressively or die, while a large company (SHARE>2) invests to keep its market share: they invest more facing a market share decrease or less if they see a market share increase. This explains that most small liners have a short life unless they can survive and become a larger company, and that larger companies invest to maintain a stable market share.

The newbuilding price index (*NBPMI*) represents the prices for both the newbuilding market and the second-hand market, as they are highly correlated. The estimated coefficient is negative, indicating that the higher the ship price, the less likely the company will acquire additional ships. This is consistent with the general expectation of demand for ships: the inverse relationship between the market price for new ships and the quantity demand, all others being equal.

The time charter index (*TCMI*) represents both the current and the expected profitability in the container shipping market. The estimated coefficient for *TCMI* is positive, indicating that pursuing high profit is one of the driving forces for ship investment.

To summarize, the empirical results reveal how liner shipping companies make ship investment decisions. Firstly, the demand for container shipping services is a positive contributor, and the time charter rate, as an indicator for market profitability, encourages the investment. Secondly, companies with larger chartering ratio tend to invest less to keep the tradition of their capacity management strategy. Thirdly, both large market share in control capacity and large market share change can increase the probability to invest. In addition, large companies invest to keep their market shares. Finally, high newbuilding price or investment cost reduces the probability of ship investment.

6.5 Concluding remarks

This chapter describes important factors for the ship purchasing decision through a theoretical analysis of the investment behavior of a hypothetical container shipping service. Then it analyses empirically the ship choice behavior of the major liner shipping companies in the world. The data used in this study involved 153 companies' investment activities from 1999 to 2009 from Alphaliner, supplemented by economic and market information from CSIN and Drewry. It adopted the binary logit model for the ship purchasing decision.

The empirical result confirms the market-driven investment behavior. The probability for investment increases with high demand, high demand increase rate, and higher charter rate. In addition, it reveals the capacity management strategy of liner shipping companies: those with larger chartering ratio tend to invest less. Furthermore, the statistical results may ease the public concerns for the market concentration in liner shipping: Although larger companies have high probability of ship investment, they tend to maintain their market shares at a stable level. For example, the market share of Maersk line was maintained at around 11 to 15 per cent between 2000 and 2008, while that of Evergreen fluctuated around 5 per cent in the same period. This finding is consistent with Fan, Luo & Wilson (2011), which reveals that the survived smaller companies grow faster than larger companies. Lastly, high newbuilding price reduces the probability of ship investment, and reveals the inverse demand relation between market price and the quantity demanded.

Chapter 7: Ship choice decisions

7.1 Introduction

Chapter 6 analyzes the decision making process of ship investment. Having decided to invest, the next decision facing a liner company is which type and which size of vessels to buy. Whatever the motivations behind the investment decision, once decide to invest, the next question is which kind of vessel to buy. There are two kinds of decision procedures in selecting a particular ship in the ship choice decision which are illustrated in Figure 7-1 and 7-2. The first decision procedure is a type priority model, which proposes that the liner company will first decide whether to order a new ship or buy a second-hand vessel before decide on the specific size of ship to buy. The second decision procedure is called a size priority model, in which the company will first decide on which size of ship do they need, and then make the final decision on the type of vessels, a newbuilding or a second-hand vessel.

Figure 7-1: Ship type priority decision procedure

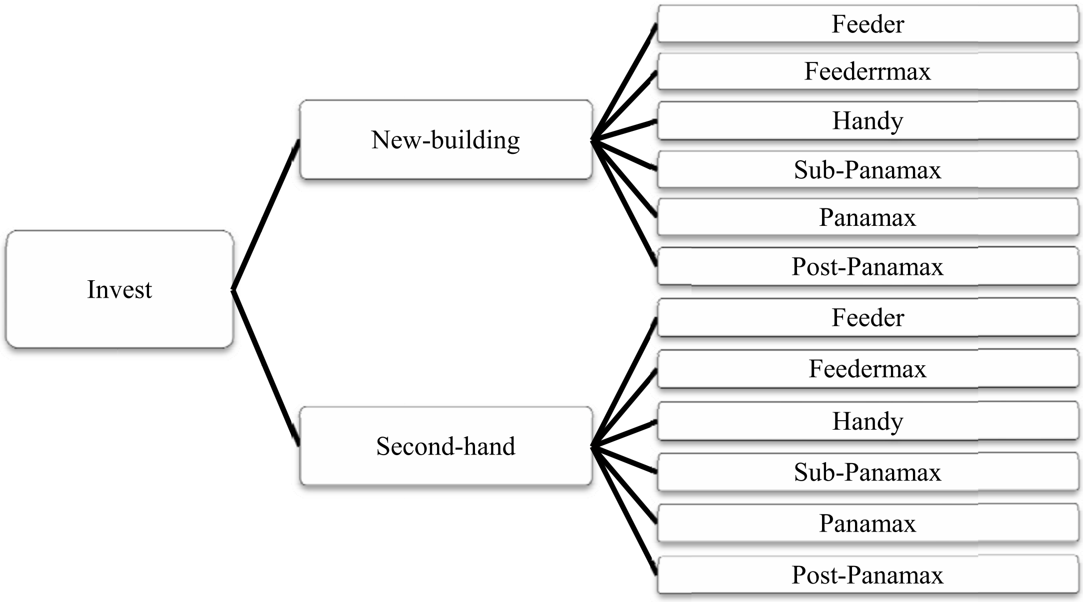
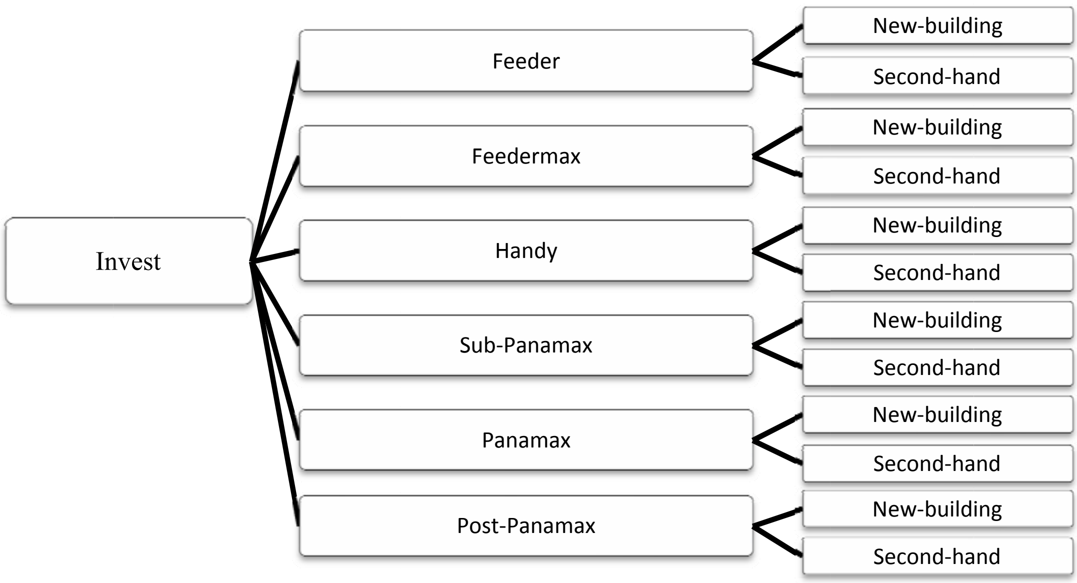


Figure 7-2: Ship size priority decision procedure



This question is obviously an unordered-choice mode which can be motivated by a random utility model. For the *i*th vessel faced with *J* choices, suppose that the utility of choice *j* is

$$U_{ij} = \beta \times choice\ \ specific\ \ characteri\ stics + other\ \ factors\ = Y_{ij}'\beta + \varepsilon_{ij}\ , \quad (7\text{-}1)$$

where β is a vector of parameters to be estimated and Y_{ij} the vector of explanatory variables which includes choice-specific variables. If the decision maker makes choice *j* in particular, assuming U_{ij} as the maximum among the *J* utilities, the probability that vessel *i* chooses alternative *j* between *j* and *k* is

$$P(Y_i = j) = \Pr ob(U_{ij} > U_{ik}) \quad for\ \ all\ \ other\ \ k \neq j\,. \qquad (7\text{-}2)$$

7.2 Description of the data and variables

The data used for the ship choice model includes the observed ship-selection records for the top liner companies who ordered new ships or bought second-hand vessels from 1999 to 2009. It involves 153 companies and 1957 invested vessels, with 86% of new orders (6.9 million TEU) and 14% of second-hand vessels (1.1 million TEU). Table 7-1 lists the descriptive statistics of all the variables used in analysing the ship choice decision. The meanings of the variables are explained next.

Table 7-1: Descriptive statistics for all variables used in ship choice modeling

Variable	Unit	Mean	Std. Dev.	Minimum	Maximum
CHOICE		0.081	0.273	0.000	1.000
NEW		0.700	0.459	0.000	1.000
SECOND		0.300	0.459	0.000	1.000
NFEEDER		0.006	0.078	0.000	1.000
NFEEDERMAX		0.057	0.232	0.000	1.000
NHANDY		0.124	0.330	0.000	1.000
NSUBPANAMAX		0.064	0.245	0.000	1.000
NPANAMAX		0.213	0.409	0.000	1.000
NPOSTPANAMAX		0.235	0.424	0.000	1.000
SFEEDER		0.033	0.178	0.000	1.000
SFEEDERMAX		0.071	0.257	0.000	1.000
SHANDY		0.102	0.303	0.000	1.000
SSUBPANAMAX		0.038	0.191	0.000	1.000
SPANAMAX		0.048	0.214	0.000	1.000
SPOSTPANAMAX		0.008	0.090	0.000	1.000
UNIVC	$ Millon/ TEU	0.030	0.057	0.000	4.469
TC	$ Thousand/Day	18.485	11.831	3.200	47.000
GTC		0.007	0.071	-0.371	1.029
CONLAG	Years	1.349	1.393	0.000	10.000
THROU	Million TEU	98.926	56.822	46.079	525.285
GTHROU		0.031	0.042	-0.149	0.143
NBP	$ Millon/ TEU	40.698	27.711	7.500	122.500
SEP	$ Millon/ TEU	22.055	13.541	3.657	51.417

CHOICE is the binary dependent variable representing company's choice on a ship type: it equals to 1 if the ship type is selected; otherwise, 0. *NFEEDER*, *NFEEDERMAX*, *NHANDYSIZE*, *NSUBPANAMAX*, *NPANAMAX*, *NPOSTPANAMAX*, *SFEEDER*, *SFEEDERMAX*, *SHANDYSIZE*, *SSUBPANAMAX*, *SPANAMAX*, *SPOSTPANAMAX* are the 12 dummy variables representing different types of container vessels. *NEW* and *SECOND* are two dummy variables for new or second-hand ships, respectively. *THROU* and *GTHROU* have the same meaning as defined in the investment decision model. They are the quarterly throughput and quarterly growth rate at the time when the company makes the investment decision.

The monthly time charter rate and its monthly growth rate (*TC*, *GTC*), monthly newbuilding price (*NBP*), and monthly second-hand price (*SEP*) for each vessel type are used to represent the market situation. *UINVC* is the unit investment cost, defined as:

$$UINVC_{ijt} = \left(NEW_{ij} \cdot NBP_{jt} + SECOND_{ij} \cdot SEP_{jt}\right) / TEU_{ijt} \qquad (7\text{-}3)$$

where *TEU* denotes the size of the invested ship. This definition ensures that the *UINVC* is specific to company *i*, ship type *j*, and nest *k*.

Finally, *CONLAG* is the actual ship construction lag for the ship ordered. For the ship type, this value takes the average construction lag of that ship type. For second-hand vessels, the construction lag is 0.

7.3 Model specification

Since the choice of a specific type of vessel could be affected by not only individual characteristics but choice-specific factors as well, the conditional logit model is adopted to investigate liner companies' vessel choice behavior naturally. Table 7-2 reports the result from the conditional logit model introduced in Chapter 4. The dataset contains 1957 observations on choice among 12 vessel types (Figure 7-1 or Figure 7-2), including newbuildings and second-hand vessels. The choice-specific attributes used are: dummy variables for the types of vessels, unit cost for different type of vessel, time charter rate and growth of time charter rate at the time when the vessel bought, the interactive variables between newbuildings and construction lag and growth of demand.

Table 7-2: Conditional logit model for ship choice

Parameter	Estimate	Standard Deviation	t-Value	P-Value
NFEEDER_L1	-3.227	0.570	-5.66	<.0001
NFEEDERMAX_L1	1.754	0.448	3.92	<.0001
NHANDY_L1	5.263	0.393	13.39	<.0001
NSUBPANAMAX_L1	5.152	0.350	14.74	<.0001
NPANAMAX_L1	5.908	0.320	18.44	<.0001
NPOSTPANAMAX_L1	8.389	0.369	22.77	<.0001
SFEEDER_L1	-5.313	0.555	-9.57	<.0001
SFEEDERMAX_L1	-1.463	0.452	-3.24	0.0012
SHANDY_L1	2.141	0.361	5.92	<.0001
SSUBPANAMAX_L1	1.269	0.302	4.2	<.0001
SPANAMAX_L1	1.771	0.270	6.55	<.0001
UNIVC_L1	-456.949	15.523	-29.44	<.0001
TC_L1	0.2322	0.017	13.74	<.0001
GTC_L1	-3.526	1.001	-3.52	0.0004
NEW×CONLAG_L2G1	0.157	0.053	2.96	0.0031
NEW×GTHROU_L2G1	-6.904	1.634	-4.23	<.0001
Number of Observations	1957			
Number of Cases	23484			
Chi-Square	4577.2			
Log Likelihood	-2574			
McFadden's LRI	0.4706			

Are the odds ratios introduced in Equation 3-31 really independent from the presence of other alternatives? To use the Hausman-McFadden test (Equation 3-32), the choice NFEEDER is eliminated from the choice set and an 11-choice model is estimated using the same conditional logit model. Since 12 vessels were invested in this mode, these observations were deleted from the choice set of 1 957 observations. Thus, the parameter on NFEEDER could not be estimated in the restricted model. The test would be based on the two estimators of the remaining 15 coefficients in the model (see Table 7-2). The results for the test are as shown in Table 7-3. There are two parts in Table 7-3, the upper part are the estimated coefficients (β_a) and their covariance matrix (Ω_a) from the full set of alternatives (12-choice model). The lower part lists the same estimates of β_b and Ω_b obtained from the restricted subset of alternatives (11-choice model).

Using Equation 3-32, $(\beta_a - \beta_b)'(\Omega_b - \Omega_a)^{-1}(\beta_a - \beta_a)$, the estimator for the chi-square distribution when IIA holds is 66. The hypothesis that the odds ratios for the other 11 choices are independent from New Feeder ship would be rejected based on these results, as the chi-square statistic exceeds the critical value of $\chi^2_{0.01}(15) = 30.58$. Since IIA is rejected, nested logit models following Figure 7-1 and 7-2 will be estimated in the following section.

Table 7-3: Results for IIA test

	Full Choice Set														
Parameter	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Estimate	-2.700	4.088	0.848	7.181	4.016	6.621	2.644	6.946	2.689	9.411	-443.688	0.282	-3.754	0.093	-7.373
	Estimated Asymptotic Covariance Matrix														
SFEEDER	0.104														
NFEEDERMAX	0.019	0.055													
SFEEDERMAX	0.057	0.028	0.059												
NHANDYSIZE	0.003	0.052	0.022	0.074											
SHANDYSIZE	0.035	0.037	0.042	0.042	0.055										
NSUBPANAMAX	-0.006	0.050	0.016	0.073	0.042	0.096									
SSUBPANAMAX	0.028	0.033	0.038	0.044	0.050	0.054	0.076								
NPANAMAX	-0.010	0.046	0.012	0.072	0.041	0.097	0.064	0.119							
SPANAMAX	0.021	0.031	0.033	0.048	0.051	0.067	0.073	0.086	0.103						
NPOSTPANAMAX	-0.024	0.053	0.005	0.085	0.041	0.111	0.063	0.130	0.086	0.152					
UNIVC	2.112	-1.135	0.687	-2.332	-0.729	-2.324	-0.485	-1.847	-0.441	-2.931	225.216				
TC	0.000	0.001	0.000	0.001	0.000	0.000	-0.001	-0.002	-0.002	-0.001	-0.139	0.000			
GTC	0.013	-0.005	0.007	-0.006	0.000	-0.001	0.005	-0.001	0.010	-0.005	0.895	-0.001	1.015		
NEW×CONLAG	0.006	-0.003	0.005	-0.003	0.004	-0.004	0.004	-0.005	0.003	-0.007	0.024	0.000	0.000	0.003	
NEW×GTHROU	0.063	-0.023	0.046	-0.057	0.033	-0.073	0.025	-0.083	0.022	-0.092	1.633	0.001	0.031	0.000	2.656
	Restricted Choice Set														
Parameter	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Estimate	-5.852	1.652	-1.779	5.433	2.065	5.381	1.218	6.116	1.771	8.773	-495.981	0.248	-3.441	0.169	-7.563
	Estimated Asymptotic Covariance Matrix														
SFEEDER	0.329														
NFEEDERMAX	0.199	0.207													
SFEEDERMAX	0.243	0.180	0.214												
NHANDYSIZE	0.133	0.165	0.132	0.159											
SHANDYSIZE	0.169	0.149	0.154	0.123	0.134										
NSUBPANAMAX	0.080	0.125	0.087	0.128	0.091	0.125									
SSUBPANAMAX	0.115	0.104	0.107	0.091	0.095	0.075	0.092								
NPANAMAX	0.035	0.084	0.047	0.096	0.059	0.101	0.060	0.105							
SPANAMAX	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.073						
NPOSTPANAMAX	0.015	0.089	0.036	0.108	0.057	0.116	0.059	0.117	0.063	0.141					
UNIVC	4.368	0.225	2.413	-1.566	0.398	-1.894	0.289	-1.656	0.000	-2.977	281.167				
TC	0.004	0.005	0.004	0.005	0.004	0.003	0.002	0.001	0.000	0.001	-0.129	0.000			
GTC	-0.009	-0.026	-0.014	-0.022	-0.016	-0.013	-0.008	-0.011	0.000	-0.015	0.858	-0.001	1.040		
NEW×CONLAG	0.000	-0.008	0.000	-0.007	0.000	-0.008	0.000	-0.008	0.000	-0.010	-0.003	0.000	0.001	0.003	
NEW×GTHROU	0.035	-0.056	0.017	-0.094	0.004	-0.109	0.000	-0.116	0.000	-0.127	2.018	0.000	0.013	0.001	2.805

Note: Numbers in the first row are the variable names listed in the first column in the same sequence.

7.4 Empirical results of nested logit model and discussion

The nested logit model is performed following the proposed procedures in Figure 7-1 and 7-2. The coefficients of the inclusive values for the nest structure in Figure 7-2 are beyond [0 1], implying that the size priority selecting structure is rejected by the empirical data in the container shipping industry. However, the nested logit result for the type priority structure is supported by the empirical analysis, which is reported in Table 7-4.

Table 7-4: Nested logit model for ship choice

Parameter	Estimate	Standard Deviation	t-Value	P-Value
NFEEDER_L1	10.504	5.601	1.88	0.0608
NFEEDERMAX_L1	20.682	5.639	3.67	0.0002
NHANDYSIZE_L1	28.435	5.670	5.02	<.0001
NSUBPANAMAX_L1	30.160	5.676	5.31	<.0001
NPANAMAX_L1	31.234	5.668	5.51	<.0001
NPOSTPANAMAX_L1	35.711	5.699	6.27	<.0001
SFEEDER_L1	-8.207	0.755	-10.87	<.0001
SFEEDERMAX_L1	-2.208	0.582	-3.79	0.0001
SHANDYSIZE_L1	3.184	0.441	7.21	<.0001
SSUBPANAMAX_L1	2.011	0.331	6.08	<.0001
SPANAMAX_L1	1.771	0.270	6.55	<.0001
UNIVC_L1	-824.669	30.420	-27.11	<.0001
TC_L1	0.369	0.024	15.48	<.0001
GTC_L1	-3.776	1.221	-3.09	0.002
NEW×CONLAG_L2G1	-2.600	0.750	-3.47	0.0005
NEW×GTHROU_L2G1	-4.041	1.420	-2.85	0.0044
INC_L2G1C1	0.323	0.036	9.09	<.0001
INC_L2G1C2	0.397	0.056	7.08	<.0001
Number of Observations	1957			
Number of Cases	23484			
Chi-Square	5151.2			
Log Likelihood	-2287			
McFadden's LRI	0.5296			

Note: * Significant at the 0.1 level; ** Significant at the 0.05 level; ***Significant at the 0.01 level; two-tailed test.

The coefficients of the inclusive variables (INC_L2G1C1 and INC_L2G1C2) are highly significant and between zero and one. This indicates that the statistical results support the assumption on shipping companies' decision-making processes – shipping companies select new or second-hand ships first, then ship size. This may be because ship investment always has different objectives. New order decisions are often made when a company has a long-term plan to build up its capacity, while buying second-hand ships is usually for satisfying the immediate needs for capacity, or for taking advantage of the low price.

The estimated coefficients on ship-type dummies indicate investors' preferences over second-hand Post-Panamax vessels – the base dummy variable for ship-types. For new vessels, the results reveal that larger vessels are preferred than smaller ones. This reflects the continuous pursuance of economies of scale in the shipping industry. However, the preference is not the same for second-hand vessels. Handysize is the most preferred type, and the preference decreases with the increase of vessel size. The least preferred ships are the vessels smaller than the handysize.

The coefficient of *UINVC* is negative, suggesting that high investment 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 earning potential. These two coefficients reveal the profit maximizing behavior in liners' ship choice. However, the coefficient on *GTC* is negative. This may be because high *GTC* often happens when the time charter rate is low. It is also possible that the high *GTC* is a sign of market volatility and uncertainty. A higher increasing rate means a less stable market and a higher risk in ship investment. Therefore, the investors may hesitate to make investment decisions when *GTC* is high.

The interactive variables with prefix *NEW*× reveal the preferences for new ships. The negative coefficient for *NEW*×*CONLAG* implies that long shipbuilding lag will reduce the preference for new ships. The negative coefficient on *NEW*×*GTHROU* shows that new ships are not as attractive as the second-hand ones when the demand growth rate is high. This is because second-hand ships can meet immediate market demand and earn quick revenue.

Having explained the impacts of variables on the ship selection behavior, it demonstrates how a change in one variable of a ship type affects the preferences on all ship types. This analysis is particularly helpful to understand the change of preferences, and the substitution pattern among all the ship types. For example, it can help to identify the change in the preferences for each ship type if the unit investment cost for a new Panamax container vessel increases by one per cent.

Based on Greene (2003), the elasticity of selecting a ship type j in nest k for a change of an attribute for ship type j^* and nest k^* ($\eta^{jk}_{j^*k^*}$) is:

$$\eta^{jk}_{j^*k^*} = \frac{\partial \ln prob(j,k)}{\partial \ln x_{j^*k^*}} = \left[1_{k=k^*} \cdot (1_{j=j^*} - p_{j|k}) + \tau_k (1_{k=k^*} - p_k) p_{j|k}\right] \beta_x x_{j^*k^*} \quad (7\text{-}4)$$

Where x_{j*k*} is the variable for ship type j^* in nest k^*, and β_x is the estimated coefficient for that variable. This equation can be further simplified into three different cases: (a) own-elasticity: the elasticity for the ship type with an attribute change; (b) cross-elasticity: the elasticity for the ship type in the same nest as the ship type with an attribute change; and (c) cross-nest elasticity: the elasticity for the ship that belongs to a different nest:

$$\eta_{j^*k^*}^{jk} = \beta_x x_{j^*k^*} \times \begin{cases} [(1-p_{j^*|k^*}) + \tau_{k^*}(1-p_{k^*})p_{j^*|k^*}] & \cdots\cdots j = j^* \; and \; k = k^* \quad (a) \\ [-p_{j^*|k^*} + \tau_{k^*}(1-p_{k^*})p_{j^*|k^*}] & \cdots\cdots j \neq j^* \; and \; k = k^* \quad (b) \\ -\tau_{k^*} p_{k^*} p_{j^*|k^*} & \cdots\cdots j \neq j^* \; and \; k \neq k^* \quad (c) \end{cases} \tag{7-5}$$

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 7-5b), which is different from cross-nest elasticity (from 7-5c). Based on the actual ship selection behavior, these three categories of elasticity for a change in the unit cost of each ship type is calculated, which is presented in Table 7-5.

Table 7-5: Ship selection elasticity with respect to the unit investment cost of each ship type

Elaticity	NFeeder	NFeedermax	NHandy	NSubpanamax	NPanamax	NPostpanamax
NFeeder	-4.416	1.885	3.199	1.196	2.622	2.384
NFeedermax	0.819	-6.626	3.199	1.196	2.622	2.384
NHandy	0.819	1.885	-11.014	1.196	2.622	2.384
NSubpanamax	0.819	1.885	3.199	-19.343	2.622	2.384
NPanamax	0.819	1.885	3.199	1.196	-24.036	2.384
NPostpanamax	0.819	1.885	3.199	1.196	2.622	-39.455
SFeeder	0.058	0.372	0.806	0.369	0.891	0.873
SFeedermax	0.058	0.372	0.806	0.369	0.891	0.873
SHandy	0.058	0.372	0.806	0.369	0.891	0.873
SSubpanamax	0.058	0.372	0.806	0.369	0.891	0.873
SPanamax	0.058	0.372	0.806	0.369	0.891	0.873
SPostpanamax	0.058	0.372	0.806	0.369	0.891	0.873
Cross-nest ratio	14.195	5.068	3.971	3.245	2.944	2.730
Elasticity	**SFeeder**	**SFeedermax**	**SHandy**	**SSubpanamax**	**SPanamax**	**SPostpanamax**
NFeeder	0.179	0.268	0.324	0.107	0.116	0.020
NFeedermax	0.179	0.268	0.324	0.107	0.116	0.020
NHandy	0.179	0.268	0.324	0.107	0.116	0.020
NSubpanamax	0.179	0.268	0.324	0.107	0.116	0.020
NPanamax	0.179	0.268	0.324	0.107	0.116	0.020
NPostpanamax	0.179	0.268	0.324	0.107	0.116	0.020
SFeeder	-2.314	1.170	1.790	0.751	1.393	0.237
SFeedermax	0.628	-3.788	1.790	0.751	1.393	0.237
SHandy	0.628	1.170	-7.613	0.751	1.393	0.237
SSubpanamax	0.628	1.170	1.790	-11.848	1.393	0.237
SPanamax	0.628	1.170	1.790	0.751	-15.205	0.237
SPostpanamax	0.628	1.170	1.790	0.751	1.393	-16.361
Cross-nest ratio	3.515	4.368	5.517	7.005	11.961	11.961

Note: the prefix 'N' and 'S' refer to the newbuilding and second-hand groups.

In this table, the upper part in white shows the elasticity for the unit investment cost change of new vessels, while the lower part in grey outlines that for second-hand vessels. The last column is the cross-nest ratio, defined as the cross-elasticity over cross-nest elasticity. This table exhibits several interesting properties:

1. The own-elasticity is always negative, while cross-elasticity is always positive. This indicates the substitute pattern in ship selection: When the price of a ship type increases, liners will select other ship types.
2. Cross-elasticity is always higher than cross-nest elasticity. This reflects the higher possibility of substitution for the ships in the same nest, than that in different nests.
3. Generally, the larger the ship size is, the higher the absolute value of the own elasticity will be. This indicates that demand for large ships is more sensitive to the unit cost than that for smaller ones.
4. The cross-nest ratios bespeak the substitution pattern between new ships and second-hand ones with the same size. In the upper part, this ratio decreases with the increase of ship size. This means that when larger new vessels increase the unit investment cost, it is easier for them to find a substitute from second-hand vessels than the smaller ones. This is because most of the large second-hand vessels are newer than the smaller ones. In the lower part, these ratios exhibit an opposite trend: It increases with the ship size. This means when larger second-hand vessels increase the unit investment cost, it is harder to find a substitute new vessel than the smaller ones. A possible

explanation may be that the smaller new vessels take less time to build than a larger new containership.

To summarize, the empirical result reveals how liner shipping companies select the type of ships to suit their own needs. The nested logit model for ship choice behavior reveals the preferences of liners over different kinds of ships, used or new, small or large, from three different aspects. First, the statistical result supports the hypothesis that shipping companies decide whether to buy a new or second-hand ship before selecting the ship size. This is because the purposes of ship investment are different for new ships and second-hand ones. Investing in new ships is frequently the result of a long-term plan for capacity development, while purchasing a second-hand vessel is either to satisfy the immediate needs, or to take advantage of low second-hand price when the market is slow. Second, new ships are generally preferred than second-hand ones. In addition, larger new ships have higher preference than the smaller ones, reflecting the pursuance of economies of scale in investing new ships. In contrast, in the second-hand market, the most frequently chosen ship type is handysize, and the chosen probability decreases with the increase of ship size. The least preferred second-hand vessels are the ships that are smaller than the handysize. Third, ships that can bring larger profit (higher time charter rate and lower unit cost) are preferred. Fourth, both long shipbuilding lag and high demand increasing rate will reduce the preference for new ships. Finally, the substitution between new and second-hand ships with the same size displays opposite patterns. It is easier to substitute larger new ships than the smaller ones. On the other hand, it is much easier to find replacement for smaller second-hand vessels.

7.5 Concluding remarks

This chapter analyses empirically the ship choice behavior of the major liner shipping companies in the world. The data used in this study involved 153 companies and 1957 vessels invested from 1999 to 2009 from Alphaliner, supplemented by economic and market information from CSIN and Drewry. It adopted the nested logit model for the ship selection decision.

The empirical results support the assumption for the decision making process for ship investment: companies decide to purchase a new or a second-hand ship before selecting the ship size. Generally, new vessels are preferred than the second-hand ones. However, long shipbuilding lag and high demand growth rate will reduce the preference for new vessels. In second-hand vessels, the most preferred vessel type is handysize, and the preference decreases when the ship size increases. In addition, ships that can bring larger profit (higher time charter rate and lower unit investment cost) are preferred. Finally, for both new and second-hand vessels, the preferences for larger vessels are more sensitive to the change in the unit investment cost. For new ships, it is much easier to find a second-hand substitute when the unit investment cost of a larger vessel increases. However, when second-hand vessels increase the unit investment cost, it is easier for smaller vessels to find a new substitute.

Chapter 8: Summary and conclusions

8.1 Main findings

This thesis examines market movements, capacity expansion and investment behavior in the container liner shipping industry. It first investigates movements in the market capacity and freight rate using dynamic market analysis. After that, it further analyzes the capacity expansion behavior from individual liner companies' perspectives and their decisions over investment and selection of ships.

Chapter 4 is concerned with the market movement and adjustment principles in the container liner market, by building a dynamic-economic model for the container shipping market and testing it using annual data from past observations.

The theoretical model postulates the changes of equilibrium in freight rates under supply and demand shifts in the container shipping market. The world container fleet capacity is augmented by the number of new orders, which is proportional to the industrial profit earned two years before. The quantity demanded of container transportation services is assumed to be exogenously determined in the model. Using the estimated result, it predicted the future container market fleet and freight rate from 2010 to 2013, based on different assumptions of the future growth rate of container transportation demand. The result shows that the freight rate would continue to decrease until 2010, but could recover quickly, because of the low ordering due to the low industry profit. This further leads to low capacity expansion in the market.

Chapter 5 identifies and tests the major factors contributing to the capacity growth of individual liner companies, using empirical analysis of panel data methods. Model results suggest that the capacity expansion of larger companies is lower than the smaller ones. This rejects the Gibrat's law that claims independence between growth rate and company size, provides an opportunity to control market concentration from individual carriers. The capacity growth of the liner company shows three distinctive patterns. Among the top 10 LSCs, some are constantly gaining market share and become the potential dominating players in the market, while others are continuously losing its share. This indicates the possibility of market concentration. The rest of the companies are having alternative increasing and decreasing shares over time. Facing aggregated expansion of all other companies, the carriers in the top 20 list respond with expanding faster, while the others reduce its expansion rate. M&A significantly increases the capacity growth of companies, except for the top 3 carriers. For them, M&A has a negative impact on the capacity growth rate.

Chapter 6 concerns the investment decisions of liner companies through theoretical modeling and empirical analysis. Result from this chapter suggests that the probability for investment increases with high demand, high demand increase rate, and higher charter rate. In addition, it reveals that companies with a larger chartering ratio tend to invest less. Furthermore, larger companies tend to maintain their market shares at a stable level. Lastly, high newbuilding price or investment cost reduces the probability of ship investment. Chapter 7 further investigates the selection of ships when liner companies invest in ships. They are found to choose a new or second-hand ship first and then to choose the size of the ship. Generally, new vessels are preferred to second-hand ones. However, the preference for new vessels is decreased with a long shipbuilding lag and high demand growth rate. The empirical estimate also suggests that ships are more preferred if they can bring a larger profit. .The preferences for larger vessels are more sensitive to the change in the unit investment cost. Finally, this research also tests the substitution pattern among different types of ship. It finds that when the unit investment cost increases, it is much easier to find a second-hand substitute for a larger new vessel. However, it is easier to find a new substitute for a smaller second-hand vessel.

8.2 Implications for academics

Despite the significant contribution made by container shipping to the world's seaborne trade and the importance of market capacity movement, literature on economic modeling and statistical analysis of the container shipping market is scarce, especially with regard to capacity expansion and investment. This study contributes to the shipping academic analysis in the following three aspects.

First, it has filled in a gap in the maritime economics by building a dynamic-economic model for the container shipping market and to test it using annual data from past observations. Furthermore, it reveals the significance of collective market adjustment principles using the observed data, but without involving complexities in individual behavior analysis, such as market competition strategies, speculation, and hedging.

Second, this research has investigated the problem of market concentration from the differential growth rate of individual firms, while the existing literature in market concentration is limited to evaluating the level of concentration in the market. Searching from the literature, most of the former studies analyzed the company growth by testing the Gibrat's law of the correlation between company growth rate and its size. Their conclusion either support or reject the Gibrat's law. Using panel date methods, this research has not only rejected the Gibrat's law, it has also identified the major factors determining a liner company's capacity growth rate as well. These factors include market conditions, company's properties, competition among companies, and M&As of the company.

Finally, through discrete choice models, this research analyzed the liner companies' behavior in vessel investment and selection, which is missing in the literature. It explored the important factors in ship investment by analysing the actual ship purchasing decisions and ship choice records of the liner companies in the world. In addition to this, it also innovatively applied the nested logit model in liner companies' choices of ships among different types of vessels. The nested logit model not only supports the assumption on the ship choice procedure, but also identifies the determinants of choices. Most importantly, this nested logit model revealed liners' preferences over different types of vessels, and substitution pattern among them.

8.3 Implications for practitioners

From the discussion above, three key policy implications are highlighted on the container shipping practice.

First, the container fleet capacity is market driven, and the impact of capacity investment on the market will not be effective until the new orders are delivered to the market. This leads to the periodic excessive capacity and the fluctuation of the freight rate. In addition, although different liner companies may have different strategies in placing new orders, on the market level, the number of new orders is proportional to the market profitability. Using the prediction from the market dynamic-economic model, decision makers of both public policy and private business can determine their best strategies on capacity investment, so as to mitigate the negative impact due to the fluctuation of the freight market.

Second, this study provides insights into the capacity expansion behavior and market concentration for container liner shipping companies of different sizes and market shares under different market situations, which can benefit not only private sectors associated with the shipping industry, but also public policy-makers in national and international maritime agencies. Understanding the current practices in shipping capacity expansion behavior can help shipping companies, shipowners and ship operators find the best opportunities to expand their capacity so as to secure their market position. For the institutions providing ship financing, and organizations in ship trading, this can help them better understand individual shipping capacity expansion behaviors, so as to provide a better service to their customers and to help reduce the risks in ship financing. For the public sector, knowing the capacity expansion behaviors can help both national and international agencies advise appropriate maritime policies to regulate the capacity investment activities so as to mitigate the impact of alternating over-capacity and supply shortages in the container liner shipping industry.

Finally, the analysis of liner companies' behavior in ship investment and choice provided useful information on ship choice preferences. The statistical results support the assumption that shipowners select new or secondhand ships before choosing ship size. The ship preference can provide practitioners with market information for different kind of ships, which can benefit their ship investment decisions. Furthermore, the substitution pattern among different types of vessels can help ship builders in pricing the new orders or new ships in the market, and shipowners in their decision regarding making new order or buy/sell secondhand ships.

8.4 Limitations and further research of this study

This research focuses on the capacity expansion and ship investment behavior of major liner shipping companies, but not on the capacity management strategy for each of the companies' shipping routes. It does not capture the strategic behavior in capacity investment among competing companies serving the same route, which could be one direction for further studies. In addition, according to the practice in the container shipping industry, some mega carriers may be more concerned with the vessel size before deciding on newbuilding or second-hand ships. So, further extension may disaggregate the data by ship size or company size. Lastly, this study explains the ship investment behavior, not chartering. It is recognized that ship chartering is an indispensable part of the controlled capacity for major liners. Understanding the rationale of ship chartering requires much detailed analysis and information concerning the chartered ships, as well as the business management strategy of each company. This can be another possible direction for future research.

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Appendix

The optimization problem described in equation (6-1) can be solved using Karush-Kuhn-Tucker method. First, the Lagrangian equation can be written as:

$$\begin{aligned}\zeta = Pn\frac{s\rho}{L}K - n_1 C_1 - n_2 C_2 - n\frac{s\rho}{L}V(s) - (N-n)LC + \lambda_1 (Q - n\frac{s\rho}{L}K - a_1^2) \\ + \lambda_2 (N - n_1 - n_2 - a_2^2) + \lambda_3 (\bar{s} - s - a_3^2)\end{aligned} \qquad (A.1)$$

The first derivatives for the control variables (n_1, s), the Lagrangian multipliers (λ_1, λ_2, λ_3) and slack variables (a_1, a_2, a_3) are:

$$\frac{\partial \zeta}{\partial n_1} = P\frac{s\rho}{L}K - C_1 - \frac{s\rho}{L}V(s) + LC - \lambda_1 \frac{s\rho}{L}K - \lambda_2 = 0 \qquad (A.2)$$

$$\frac{\partial \zeta}{\partial s} = P\frac{n\rho}{L}K - \frac{n\rho}{L}V(s) - \frac{ns\rho}{L}V'(s) - \lambda_1 \frac{n\rho}{L}K - \lambda_3 = PK - V(s) - sV'(s) - \lambda_1 K - \lambda_3 \frac{L}{n\rho} = 0$$
(A.3)

$$\frac{\partial \zeta}{\partial \lambda_1} = Q - n\frac{s\rho}{L}K - a_1^2 = 0 \qquad (A.4)$$

$$\frac{\partial \zeta}{\partial \lambda_2} = N - n_1 - n_2 - a_2^2 = 0 \qquad (A.5)$$

$$\frac{\partial \zeta}{\partial \lambda_3} = \bar{s} - s - a_3^2 = 0 \qquad (A.6)$$

$$\frac{\partial \zeta}{\partial a_1} = -2\lambda_1 a_1 \qquad (A.7)$$

$$\frac{\partial \zeta}{\partial a_2} = -2\lambda_2 a_2 \qquad (A.8)$$

$$\frac{\partial \zeta}{\partial a_3} = -2\lambda_3 a_3 \quad \text{(A.9)}$$

If a_3=0, then $s=\bar{s}$, the vessel speed equals its up bound limit, in which case the optimal n is easy to obtain. It only demonstrates the results when $s<\bar{s}$ in this appendix, which means that $a_3 \neq 0$, and $\lambda_3=0$ (from equation A.9). Then, A.3 turns into,

$$\lambda_1 = \frac{PK - V(s) - sV'(s)}{K}. \quad \text{(A.10)}$$

Put A.10 into A.2, it gets,

$$LC - C_1 - \lambda_2 + \frac{s^2 \rho V'(s)}{L} = 0. \quad \text{(A.11)}$$

From equation A.8, there are only two cases for the solution,

1) If a_2=0, $\lambda_2 \neq 0$, from A.5, it gets $n=N$.

From A.7, there are only two cases,

a) a_1=0, $\lambda_1 \neq 0$.

Put a_1 into equation A.4, it gets solution (6-2*a*),

$$n = N, q = Q = N\frac{s\rho}{L}K$$

b) $\lambda 1=0,\ a1 \neq 0.$

From A.10, the optimal speed s_o can be calculated from $P = \frac{V(s) + sV'(s)}{K}$.

From A.4, it gets solution (6-2*b*),

$$n = N, q = \frac{ns\rho}{L} K = Q - a_1^2 < Q.$$

2) If λ_2=0, $a_2 \neq 0$, from A.5, it gets $n<N$.

From A.7, there are only two cases,

a) $a1=0,\ \lambda 1 \neq 0.$

Put a_1 into equation A.4, it gets solution (6-2*c*),

$$n = N - a_2^2 < N, q = Q = N \frac{s\rho}{L} K.$$

b) λ_1=0, $a_1 \neq 0$.

Similar to 1b, the optimal speed s_o can be calculated from

$$P = \frac{V(s) + sV'(s)}{K}.$$

From A.4, it gets solution (6-2*d*),

$$n = N - a_2^2 < N, q = \frac{ns\rho}{L} K = Q - a_1^2 < Q.$$