THE HONG KONG POLYTECHNIC UNIVERSITY

Department of Logistics and Maritime Studies

Relationships between the Freight and Ship Markets in the Dry Bulk and Tanker Sectors

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A thesis submitted in partial fulfilment of the requirements

for the Degree of Master of Philosophy

August 2010

CERTIFICATE OF ORIGINALITY

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ABSTRACT

This thesis focused on three different but interrelated markets in the international shipping industry, namely the freight market, new-building and second-hand ship markets. In each market, price was chosen as the key variable to examine the existence of the dynamic relationships among these variables for three different vessel sizes in both the dry bulk and tanker sectors. Granger causality test is then applied after controlling for the existence of cointegration.

First, the test within only the ship markets is carried out. Monthly new-building and second-hand ship prices (5-year-old and 10-year-old) for three ship types in both dry bulk and tanker sectors are selected. Results show that, in general, the second-hand ship price leads the new-building price in the dry bulk sector, while the new-building ship price leads the second-hand price in the tanker sector in most cases. This conclusion could be further confirmed when the shipping environment is booming. Finally, the hypothesis that the average dry bulk new-building ship price leads the tanker new-building ship price is tested to explain the opposite lead-lag relations, and more frequent trading activities in the dry bulk sector than in the tanker sector are concerned to interpret this conclusion.

Second, the test within three markets is conducted. The results from this part also indicated that the temporal relationships between the ocean freight and ship markets are differed in the dry bulk and tanker sectors. For the dry bulk sector, the time charter rate is an indicator of international shipping. In the counterpart, this indicator is more likely to be played by the new-building ship price. These results suggest that ship-owners or investors should make their decision of getting ships based on the change of freight market in the dry bulk sector. But for the tanker sector, ship-owners should take the change of the new-building market as an important signal. Furthermore, it can be concluded that the different structures of the dry bulk and tanker sectors are more possible to be caused by the role played by the new-building ship price or even the new-building ship market.

All the findings in this thesis suggest that the temporal relationships between the main shipping markets are more complex than previously expected. They all imply that the economic structures are obviously distinct in the dry bulk and tanker sectors. Therefore, investigations should be carefully conducted separately for the dry bulk and tanker sectors in the future.

ACKNOWLEDGEMENTS

First of all, I would like to express my deep gratitude to my supervisor Prof. Liming Liu who gave me the chance to pursue the degree of Master of Philosophy in PolyU. He is serious in research, kind in actual life and generous to provide opportunities for students. From his assistance and guidance, I learned the way of thinking in academic research and how to solve the problems. The learning process in last two years is precious in my life.

Next, I would like to give my appreciation to the staff and students in the Department of LMS. Thanks for the support by Dr. Meifeng Luo and Dr. Tsz Leung Yip in the IAME conference in Portugal. Thanks to my office colleagues, especially Chen Shou and Xiaojin Liu. Thanks for the help by Lixian Fan, Jingbo Yin, Jing Xu, Jenny Ying Xin, Liu Yang, Baozhuang Niu, Moo and Siyang Liu. Thank you for your share and help in studies and daily life.

At last, I would like to thank my family and boyfriend. Thanks for the support and understanding by my parents and grandmother. Thanks for the encouragement and consideration by my boyfriend Andy Wang. Because of you all, my life is wonderful.

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Chapter 1: Introduction

The aim of this chapter is to provide an introduction of the background of the shipping industry. Specifically, this chapter will review the main shipping markets, different shipping sectors and ship categories. Then, it will describe the research questions this thesis concerned. At last, the structure of this thesis will be presented.

1.1 The four shipping markets

Shipping is one of the world's most international industries, more than 90% world trade moves by sea[1]. It is well known that this industry is influenced by majority random events, such as oil price, economy crises, etc., meanwhile it exhibits shipping cycle characters with the average length of eight years (*Stopford 1997*). Shipping is also an industry in which the main capital assets are traded. Therefore, all participants in shipping face high risks and uncertainty.

Stopford (1997) divided international shipping industry into four closely related markets based on the linkage of cash flow in his famous book *maritime economics*, namely the freight market for trading sea transport, the second-hand market for

[1] Data Source: http://www.marisec.org/shippingfacts//worldtrade/index.php

buying and selling used ships, the new-building market for ordering new ships and the demolition market for dealing with scrap ships.

In fact, the freight market is a service market in which the cargo-owners can rent vessels for their sea transport services while the new-building, second-hand and demolition markets are all dealing with ships and can be viewed as ship markets.

The freight market is a service market for cargo transportation. This market is regulated by different types of contract which also means chartering. The contract is usually employed between the ship-owner and charterer. The ship-owner agrees to transport cargoes on a specified voyage or for a period of time, while the charterer agrees to deliver the cargoes for a certain price called freight rate. The price for one trip only is usually called a voyage rate or a spot rate. Its function is to make the demand equal to the supply in a short-run. On the other hand, the price for hiring a ship over a future period of time is defined as a time charter rate. The durations of time charters can be from months to years. Therefore, the time charter rate handles the future risk and contains the information of market expectations about the future.

The new-building, second-hand and demolition markets are all ship markets. One way for ship-owners or investors to obtain their ships is from the new-building ship market. Building new ships can directly influence the supply side of the international shipping. This new-building ship market is to make the supply of new ships equal to the demand for ships. Shipbuilding is a long-cycle business since the time-lag between ordering and delivering a ship is between 1 to 4 years depending on the size of order-book held by the shipbuilders (*Stopford 2009*). Then the price for a new ship may reflect the market expectations for the future as the function as the time charter rate. Many of ordering decisions of new ships are made when the freight rates are relatively attractive in practice, because it encourages the banks to lend more money in the expectations.

Another way for the ship-owners to get the ships is from the second-hand ship market. This market plays an important economic role in shipping industry as it links with the new-building and demolition markets. The key function of this market is to reallocate ships among ship-owners because the buyer is usually another ship-owner. Then the transactions in the second-hand market can not change the fleet size of the whole shipping industry. This market makes ship-owners facilitate to buy and sell ships, thus allowing easy entry and exit. Like other commodity, the second-hand ship price is negotiated between a buyer and a seller. A second-hand ship has a shorter trading life than a new one, it causes the second-hand ship price sometimes is more expensive than the similar new-building ship price when the freight market is very booming.

The demolition market can also affect the supply side of the shipping industry. Generally, ship demolition is a type of ship disposal when its lifespan becomes uneconomical. Ship demolition allows materials from the ship to be reused. Then, the scrapping price is impacted by the metal market. Since ship disposal is dangerous and badly paid, most demolition happened in India, Bangladesh, Turkey and Pakistan at present[2], due to their lower labour costs and less strict environmental regulations. Ship demolition sometimes is not profitable, since removing the materials from ships may cost more than the value of scrap metal itself.

Table 1-1 shows the participants and the key variables in all these four shipping markets. As can be seen, the same ship-owners are trading in these markets.

Table 1-1: The Participants in Four Shipping Markets

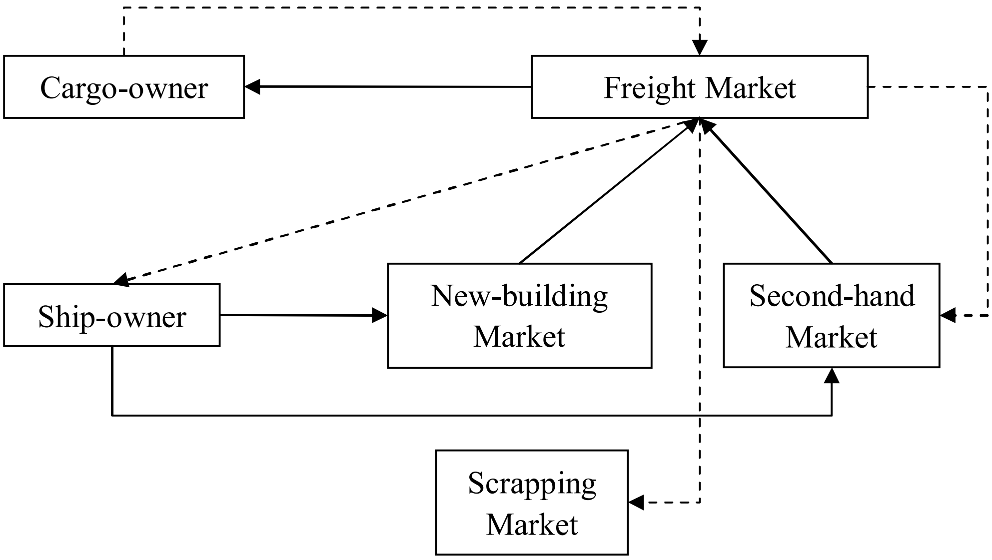
Market	Buyer	Seller	Price
Freight	Cargo-owner	Ship-owner	Freight rate
New-building	Ship-owner	Ship yard	New-building price
Second-hand	Ship-owner	Ship-owner	Second-hand price
Demolition	Breaker	Ship-owner	Scrapping price

[2] Source: http://www.shipbreakingbd.info/Shipbreaking%20around%20the%20world.html

An important point is that these markets are not independent but related to each other. In this thesis, these relations are examined from a new point of view – the direction of ship flow.

It is well known that world shipping is an economic activity directly dependent on global seaborne trade. Seaborne transport activities can then cause the demand for ships by the cargo-owners. In this circumstance, the cargo-owners will enter into a special contract with the ship-owners for hiring their ships. For the ship-owners, they have two ways to get ships: purchase an old ship immediately in the second-hand market or order a new one in the new-building market. Then ship-owners can rent out their ships in the freight market for just operating the ships for a period of time or they can also sell them to take the advantage of the value increase for speculation purpose in the second-hand market. Any decision made by the ship-owners for how to get the ships will influence the ship markets (new-building and second-hand markets) immediately. On the other hand, ship-owners have three ways to deal with the ships when the freight market is recession - to sell them in the second-hand market, to scrap them in the scrapping market or to lay-up them for a period of time. The choice they made can also affected one market to another. Figure 1-1 shows the concept of the view of ship flow.

Figure 1-1: Conceptual Relations among the Four Markets

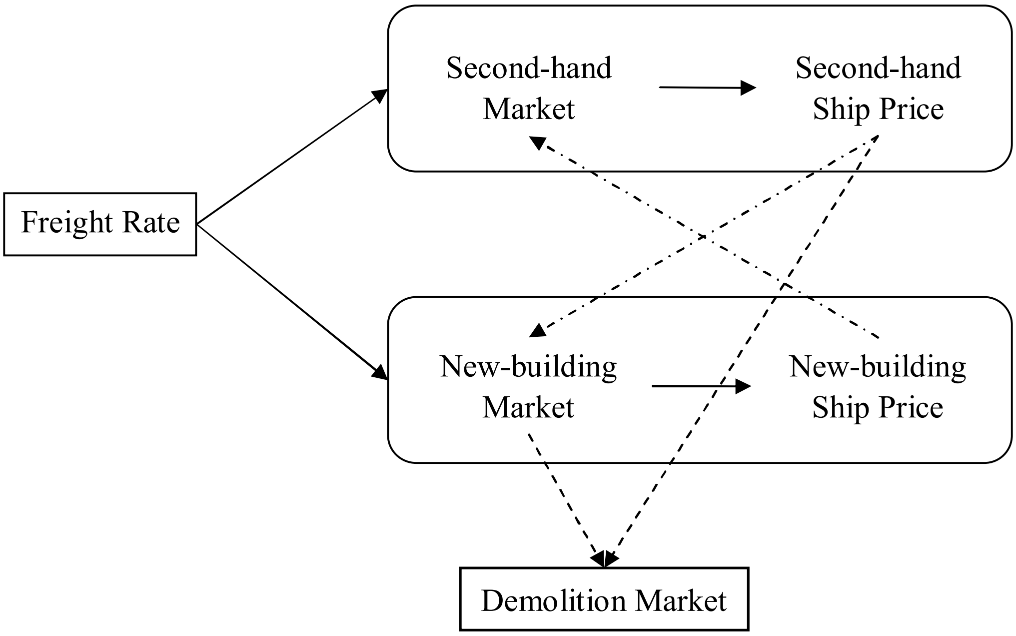


Notes: The solid line indicates ship flows from ship-owner to cargo-owner (or charterer) while the dashed line shows opposite.

Furthermore, there are also economic relationships among the typical decision making variables – prices in these four markets. Figure 1-2 indicates these economic relationships. It can be seen that if the freight rate is in an uptrend, as the earnings of ship services rise, shipping investors rush to purchase more second-hand ships immediately, and this will drive up second-hand ship price. Then a high second-hand ship price may induce ship-owners to order new ships instead and new-building price may increase accordingly. Or ship-owners can also order new ships with shipyards directly when freight rates are attractive. Similar to the alternative of buying second-hand ships, the new-building and second-hand ship prices will then be driven up, while the effect on second-hand ship price may have a time lag response.

Whatever the decision made by ship-owners, the order-book of new-building ships will increase. This activity will have a negative impact on the freight market. The continuous lower freight rate may cause the decease of second-hand ship price. If the scrapping value is higher than the second-hand value, ship-owners will scrap ships in the end. If not, ships may sell in the second-hand market. Therefore, clearly understanding of market relationships can help both cargo-owners and ship-owners in their chartering or investing strategy.

Figure 1-2: Economic Relationships among Four Shipping Markets

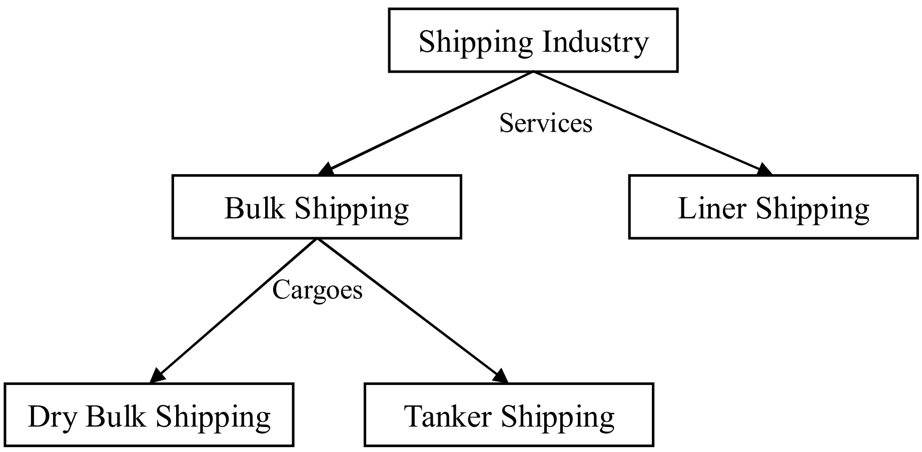


Notes: The solid line indicates direct relations, while the dashed line represents indirect relations.

1.2 Division of shipping sectors

Shipping is not one industry but consists of a number of sectors. The division of shipping industry in this thesis is given by *Bennathan and Walters (1969)* and *Metaxas (1971)*. They divided international shipping into bulk and liner shipping based on the type of services. Within the bulk shipping, it can be also separated into two sectors based on the transportation of cargoes - they are the dry bulk sector which is concerned with the dry commodities and the tanker sector in which vessels specifically carry liquid cargoes. Figure 1-3 represents the division of the shipping industry.

Figure 1-3: Division of the Shipping Industry



This thesis especially focuses on the issues in the bulk shipping industry. Therefore, the dry bulk and tanker shipping sectors are the main research area. Over

70 percent of tonnage of seaborne trade is for the energy and metal industries which associated these two sectors (*Stopford 1997*).

1.2.1 The dry bulk shipping sector

The dry bulk shipping sector is concerned with the carriage of unpackaged dry bulk commodities, such as coal, iron ore, grain, etc. The dry bulk carriers account for around 37.5% of the total world fleet in 2009[3]. The first steam ship recognized as a bulk carrier was the British coal carrier built in 1852. Forced by the development of technology and economy, the dry bulk vessels are designed to grow in their sizes and capacities. As of 2009, the largest vessel in this sector is the 364,768 metric tons deadweight (DWT) used to carry iron ore[4]. In this shipping sector, the carriers are mainly owned by Greece, Japan and China[5]. Majority of the ships were built in Asia.

The main dry bulk carriers can be segregated in to four size categories: Capesize, Panamax, Handymax and Handysize. These categories are the same as in most studies in the past. Capesize bulk carriers (80000 + DWT) are mainly used to transport iron ore and coal. These ships are too large to pass the Suez or Panama Canals and must round the Cape of Good Hope. Panamax carriers (60000 – 80000

[3] Data is collected from Website http://www.platou.com/dnn_site/Tables/Worldfleetdevelopment.aspx, and the unit is million DWT

[4] Source: Clarkson Research Services Limited 2010

[5] Source: http://money.163.com/10/0608/08/68L4NIMK002526O5.html

DWT) are used mainly for coal and grain and can pass through the Panama Canal. Handymax and Handysize carriers are the most common size which occupied 71% of all the bulk carriers[6]. Handymax carries are typically 35000 - 59000 DWT, and Handysize carriers are mainly 15000 - 35000 DWT. They can carry a wide variety of cargoes including steel products, grain and minor bulk commodities.

However, the Handymax vessels are not included within the research scope since the ship categories changed several times in the past and the classifications in the past usually consider Handymax as a sub-classification of Handysize vessels rather than a separate class[7]. Table 1-2 represents the basic structures for three main dry bulk carriers concerned in this thesis. As it shown, in 2009, the world's dry bulk fleet included 6977 ships of 418.07 million DWT, increased 4.4% measured in number and 6.6% measured in DWT. By the end of 2009, the dry bulk fleet consisted of 822 (143.3 million DWT) Capesize, 1558 (114.75 million DWT) Panamax and 2888 (76.94 million DWT) Handysize vessels which occupied 75.5% of the total dry bulk fleet. Among them, Handysize vessels are the main transportation vessels with the greatest fleet size (the number of Handysize carriers is 2888 which accounts for 41.4% of the total fleet measured in numbers[8]). In terms of numbers of units, Capesize increased 7%, Panamax increased 5.3% and Handysize increased 1.8%.

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6 Source: Clarkson Research Services Limited 2010
7 Source: http://www.glgroup.com/Dictionary/EI-Handysize.html
8 Source: Clarkson Research Services Limited 2010

The growth was relatively higher for the Capesize vessels. The order-book was 3836 (326.6 million DWT) and the demolition was 262 (10.44 million DWT) in total in this sector. The growth of order-book is highest in the Capesize segment while the increase of demolition is just opposite. This status shows that bigger ships played a central part of the dry bulk shipping. As *Stopford (2009)* pointed out that the dry bulk vessels are 10 to 15 times bigger over past 50 years. The volume of dry bulk vessels traded in 2009 was 582 (32.02 million DWT), an 87.7% increasing on last year's figures. The main reason for the dramatically increasing of transaction activities is because the world economy recession in 2008.

Table 1-2: Market Conditions for the Main Carriers in the Dry Bulk Sector

	Capesize	Panamax	Handysize	Total	Proportion
Fleet	822 (7%)	1558 (5.3%)	2888 (1.8%)	6977 (4.4%)	75.5%
Order Books	889 (31.1%)	861 (30.5%)	1052 (27.8%)	3836 (27.1%)	73%
Demolition	9 (-35.7%)	34 (100%)	192 (209.7%)	262 (151.9%)	89.7%
Sales Volume	49 (53%)	129 (104.8%)	247 (73.9%)	582 (87.7%)	73%

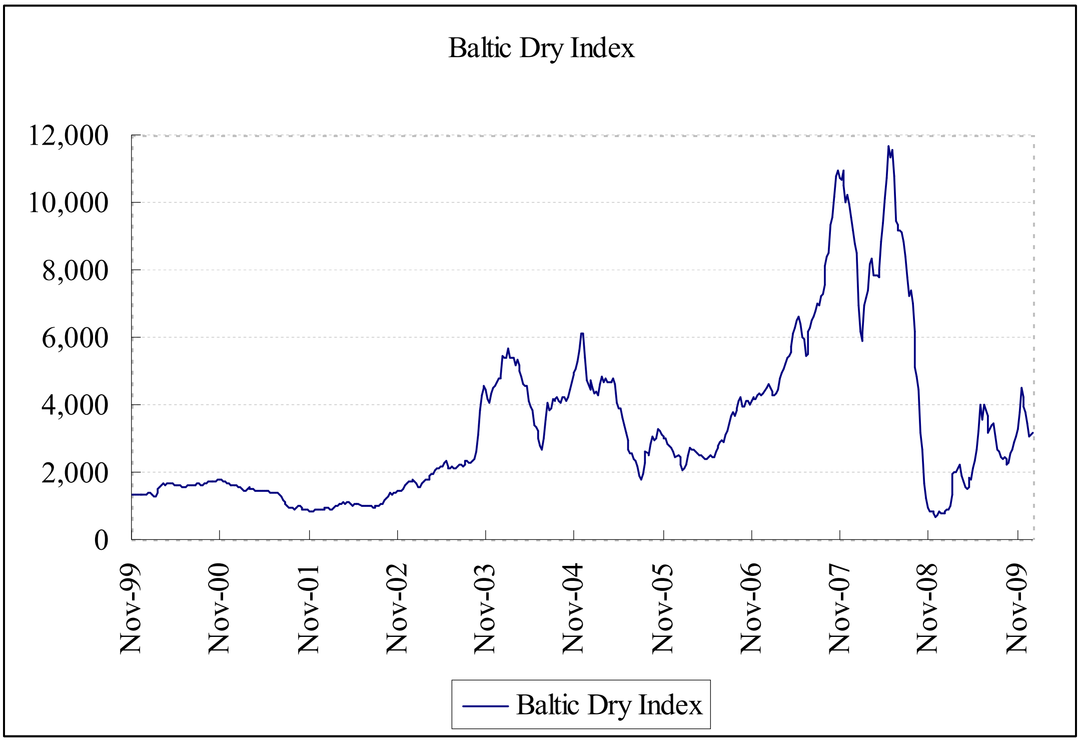
Note: Data are all yearly data measured in numbers in 2009; data in the bracket are the rate of growth comparing with the last year.
Data Source: Clarkson Research Services Limited 2010

The Baltic Dry Index (*BDI*) is a number issued daily by the London-based Baltic Exchange. The BDI was first introduced on 1 November 1999 and replaced the

Baltic Freight Index (BFI) which excluded Handysize and Capesize routes. This index tracks the worldwide international shipping prices of dry bulk cargoes including coal, iron ore and gain. It is measured on voyage and time charter basis with taking 26 shipping routes by a panel of international ship broking companies so it can be viewed as the leading indicator of shipping activity in the dry bulk sector. A chart of the weakly *BDI* is as follows in Figure 1-4.

As Figure 1-4 shown, the *BDI* index is quite volatile. A rapid growth happened (*BDI* was more than 4000) in 2003 while the growth was moderate (*BDI* was less than 2000) before this year. And the run up from 2005 to the end of 2007 was dramatic. *BDI* even exceeded 10000 in the year 2007. These extreme booming periods were primarily due to the economy and demand growth in China, for example it shifts from coal exporter to importer. However, the world economy moved into a deep recession in 2008, and caused *BDI* plummeted. In 2009, shipping economy seems recover to the level in 2005.

Figure 1-4: Baltic Dry Index



Data source: Clarkson Research Services Limited 2010

1.2.2 The tanker shipping sector

The tanker sector is concerned with the vessels to carry liquid cargoes, such as crude oil, petroleum products, wines, chemicals or anything in liquid form. In this shipping sector, the carriers for crude oil and refined oil products are the widest range. Between them, the crude oil tankers are the most common carriers moved large quantities of unrefined crude oil from its point of extraction to refineries. The first steam-powered oil tanker was built in 1886[9]. As oil companies sought to

[9] Source: http://www.aukevisser.nl/german/id95.htm

transport their cargoes more efficient and cheaper, the tanker size has grown significantly alongside the oil industry. Greece, Japan and the China are the main owners of tankers[10]. A majority of the tankers were built in South Korea, Japan and China.

Because the scope of this thesis just covers the oil tankers, the categories for only oil tankers are given here. Three main size categories are for crude oil tankers are VLCC, Suezmax and Aframax. VLCC tankers (200000 - 320000 DWT), i.e., Very Large Crude Carrier, are able to transport two million barrels of crude oil and the primary routes for these vessels are long haul. Suezmax tankers (120000 - 200000 DWT) typically engage in long to medium haul oil trades. The size of this tanker is capable to pass through the Suez Canal in Egypt. Aframax vessels (80000 - 120000 DWT) are operated in medium to short haul oil trades.

The oil tanker fleet continued to grow in 2009. By the end of 2009, there are 4920 ships of the world's tanker fleet, increased 8.1% measured in number. Table 1-3 shows the yearly data for these three ship types in the tanker sector in the year 2009. It can be seen that, in 2009, the tanker fleet comprised of 516 (153.31 million DWT) VLCC, 366 (55.74 million DWT) Suezmax and 781 (81.01 million DWT) Aframax tankers which means that VLCC increased 2.8%, Suezmax increased 0.8% and

[10] Source: http://money.163.com/10/0608/08/68L4NIMK002526O5.html

Aframax increased 5.1% measured in numbers. 1951 (180.76 million DWT) new tankers were ordered which decreased -7.3% comparing with the year 2008. 253 (78.55 million DWT) of these orders were VLCC, 181 (28.27 million DWT) were Suezmax, and 257 (28.12 million DWT) were Aframax. The growth of VLCC and Suezmax tankers was positive whilst the Aframax's growth was decline. It also shows the trend of upsizing for tanker ships. The total demolition was 139 (8.46 million DWT), increased 82.9%. The transaction volume of tankers was 146 (14.29 million DWT), decreased 41.6% last year.

Table 1-3: Market Conditions for the Main Carriers in the Tanker Sector

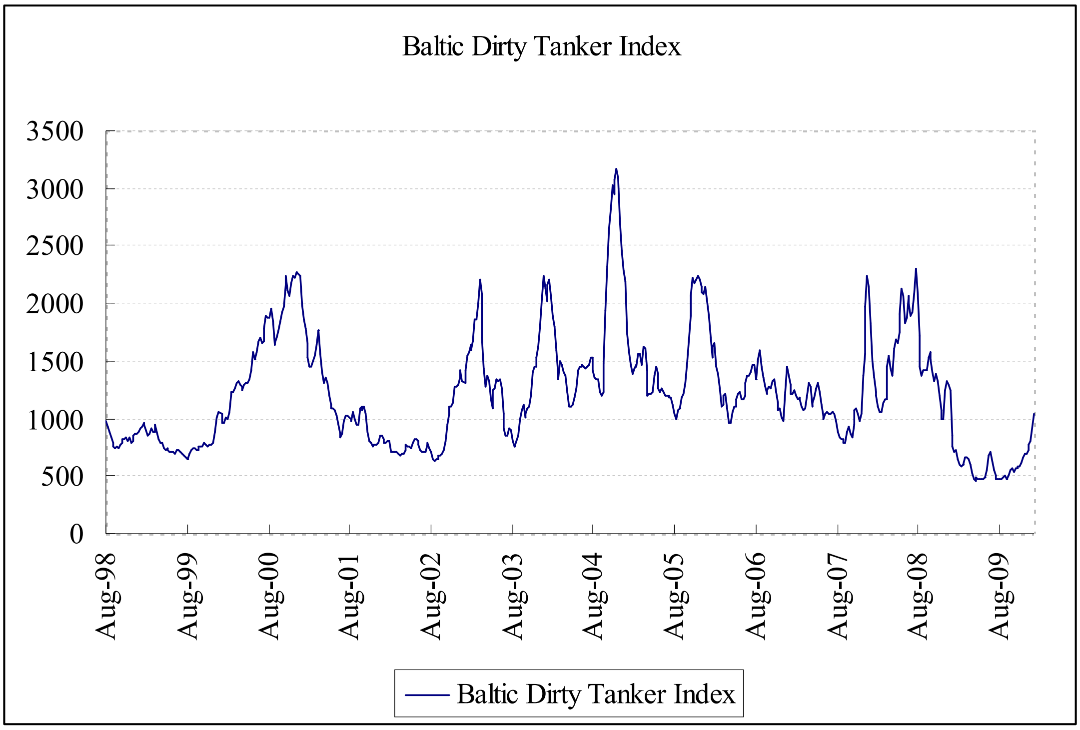
	VLCC	Suezmax	Aframax	Total	Proportion
Fleet	516 (2.8%)	366 (0.8%)	781 (5.1%)	4920 (8.1%)	33.8%
Order Books	253 (36.8%)	181 (19.1%)	257 (-11.1%)	1951 (-7.3%)	35.4%
Demolition	9 (200%)	6 (200%)	16 (33.3%)	139 (82.9%)	22.3%
Sales Volume	25 (25%)	14 (-41.7%)	22 (-62.7%)	146 (-41.6%)	41.8%

Note: Data are all yearly data measured in numbers in 2009; data in the bracket are the rate of growth comparing with the last year.
Data source: Clarkson Research Services Limited 2010

The Baltic Dirty Tanker Index (*BDTI*) is a compilation of international dirty cargoes (mainly crude oil) routes. This index was introduced in 1998. It tracks the worldwide international shipping prices of crude oil. Figure 1-5 shows the chart of the weakly *BDTI*.

The index in tanker sector is even more volatile than in the dry bulk sector. A rapid growth of *BDTI* happened in 2000, 2003-2005 and 2007. In this sector, politics has played a special role, such as the Israeli-Palestinian conflict, and the policy on 2010 phase out target for single hull tankers. Meanwhile, the growth of crude oil demand is also a main factor in this sector. The run down from 2000 to 2001 was dramatic. This may be caused by the worldwide IT Bubble in 2001 when the stock markets melted down. Since 2004, a cycle decline appeared although *BDTI* was still high. The reason behind this may be attributed to the fleet growth of tankers. Tanker sector shows an excess supply tonnage over years. Another recession triggered by the credit crisis in 2008. Therefore, the world economy impacts heavily on the shipping industry.

Figure 1-5: Baltic Dirty Tanker Index



Data source: Clarkson Research Services Limited 2010

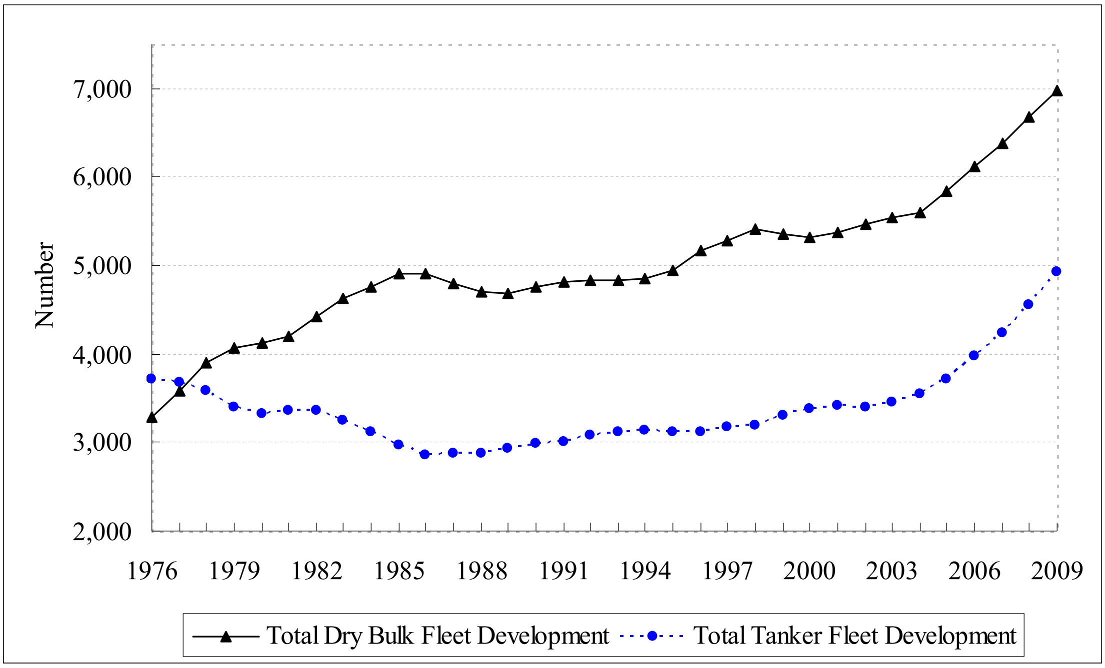
1.2.3 Comparison between the dry bulk and tanker sectors

After the introduction of the dry bulk and tanker sectors separately, the comparison between these two sectors will be analyzed next.

The dry bulk and tankers sectors are belonged to the bulk shipping, so they have similarities such as perfect competition environment (for example *Koopmans 1939, Hawdon 1978, Beenstock 1985*). Perfect competition implies that these two sectors have many buyers and sellers of freight services, with no restrictions to entry or exit, negotiating homogeneous product and with perfect information. That is, all the participants in these two sectors are price taker who cannot influence the freight rate.

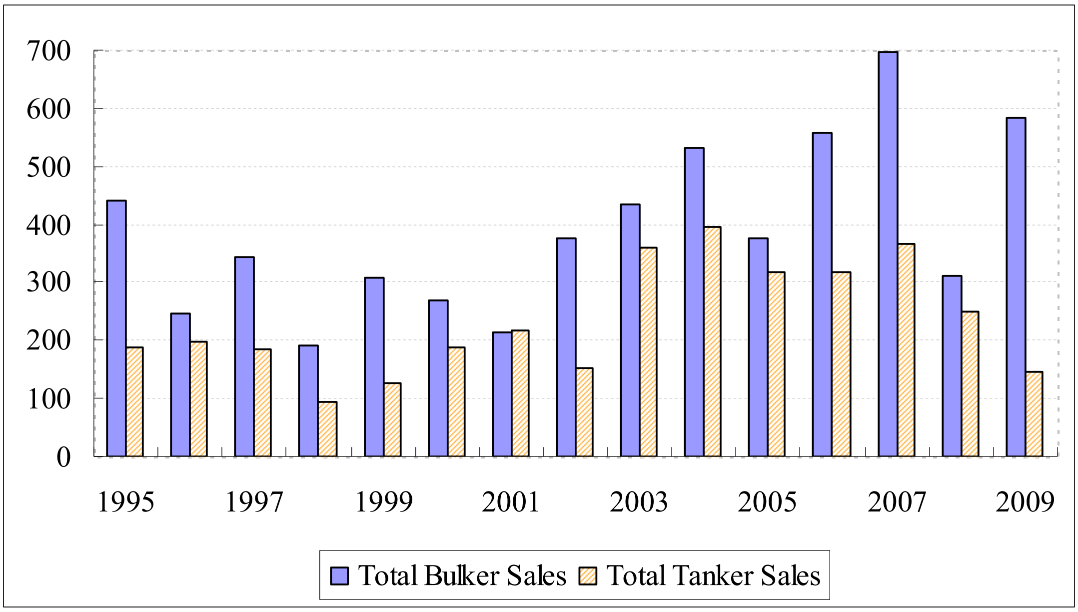
While these two shipping sectors have some similar characteristics, there exist sufficient differences obviously. For example, Figure 1-6 and Figure 1-7 show the fleet size and the total sale volumes in these two sectors. It can be seen clearly that the fleet size for the dry bulk vessels is larger than the tankers since 1978, and the trading market in the dry bulk sector is usually more active than in the tanker sector.

Figure 1-6: Fleet Size Developments in Two Shipping Sectors



Data source: Clarkson Research Services Limited 2010

Figure 1-7: Total Sale Volumes in Two Shipping Sectors



Data source: Clarkson Research Services Limited 2010

Despite the clear distinctions, such as shipping routes, the shipped cargoes and the types of vessels, etc., the economic structures are also differed for these two sectors. *Veenstra (1999)* indicated that the economic structures for the dry bulk and tanker sectors are different, and it possible to be caused by the role played by the second-hand ship price or even the second-hand ship market. *Haralambides et al. (2004)* have pointed out that the ship-owners operating in the tanker sector have more capital than those in the dry bulk sector. So the dry bulk sector is more cost driven while the tanker sector is more revenue driven. The underlying assumption is that the investing attitudes towards risk by ship-owners in these two sectors are not same.

However, past studies usually carried out their research within just one shipping sector, either the dry bulk (for example, *Alizadeh-Masoodian 2001, Kavussanos and Alizadeh 2002a, 2002b, Alizadeh and Nomikos 2003, Adland and Koekebakker 2004, Alizadeh and Nomikos 2007*) or the tanker sector (for example, *Glen et al. 1981, Beenstock and Vergottis 1989b, Kavussanos 1996, 1997, Merikas et al. 2008*). Although some of the studies have examined two sectors simultaneously (for example, *Hale and Vanags 1992, Beenstock and Vergottis 1993, Glen 1997, Tsolakis et al. 2003, Haralambides et al. 2004*), their original intentions are not to compare and emphasize the difference between these two sectors. One exception is *Veenstra (1999)*. He mentioned the possible important difference and verified it in one chapter in his thesis. However, his main concern is to provide insights into the structures of an integrated market model for the whole shipping industry. Then he used average quarterly data series (from 1980 to 1995) rather than specifying the ship categories in each sector.

1.3 Research questions

The aim of this thesis is to explore the temporal relationships between three main shipping markets (the freight, new-building and second-hand ship markets) in two different but related shipping sectors – the dry bulk and tanker sectors. In each shipping sector, three kinds of ship types are specified. For the dry bulk sector, Capesize, Panamax and Handysize carriers are concerned, while for the tanker sector, VLCC, Suezmax and Aframax ship segments are divided. Another aim of this study is to compare the differenced drawn from the dry bulk and tanker sectors.

In this thesis, the demolition market is not within the scope of the investigation. First, the history numbers of the demolition ships are relatively small. Second, ship owners do not scrap the ships as a source of income, and this decision is more influenced by the ships' age restrictions but not the scrapping ship price.

Regarding to the studies on the relationships between the freight and ship markets, past studies generally analyzed these relations under a number of regression models. In other words, these works just suggest the degree of impact between one variable on another. From these results, it is still unclear about how fast those variables respond to the new information. Since the dynamic relationships among the variables are complicated (discussion in section 1.1), it is hard to say which variable triggers the changes of another or which variable responds to the new information more quickly. It is possible that the reactions of these variables to the new information are not simultaneous all the time but have a time lead or lag relationship. Thus, in this thesis, the relationship particularly means the temporal linkage among the variables.

To analyze the temporal relationships, two main parts will be divided. In the first part, relationships between just the ship markets (the new-building and second-hand ship markets) are especially concerned. In this part, the temporal relationship between the new-building and second-hand ship prices (5-year-old and 10-year-old) is explored. The second part is an extension of the first research part. It extends the analysis on only ship markets to include the freight market.

1.3.1 Relationships within the ship markets

Lead-lag relationships between two economic variables have been studied extensively in the financial market. The generally accepted conclusion is that the future price usually leads its corresponding current price for a commodity or a financial asset (e.g., *Chan 1992, Tse 1995, Kang et al. 2006*). In shipping economics, this type of relationship has also been examined. For example, a number of authors investigated the lead-lag relationship between the spot rate and time charter rate. The finding is similar to that for the financial market, i.e. the time charter rate usually leads spot rate (*Glen et al. 1981, Kavussanos and Nomikos 2003*). Recently, the research on lead-lag relations has been extended to include ship prices. *Alizadeh and Nomikos* (*2007*) investigated the relationships between the second-hand ship price and time charter rate while *Xu et al.* (*2010*) analyzed the relationships between new-building ship prices and freight rates. Their results show that freight rates lead the ship prices in the dry bulk shipping sector.

In the shipping market, investors and ship-owners often face the choice of purchasing a new ship or a second-hand ship. Their prices are obviously related variables and how and to what degree these two prices are related have attracted the attention of the research community. A prevalent believe among some researchers is that the second-hand ship price should lead the new-building ship price because the second-hand ship price is more flexible (e.g., *Beenstock and Vergottis 1989a, 1989b*). However, in the shipping market, the liquidity for the second-hand ships is generally lower than that of the new-building ships. Then the second-hand ship price may not be flexible enough as past researchers expected. Furthermore, because of the time lag between ordering and delivery of a new ship, the new-building ship price should reflect the expectation of the future market conditions and have a similar property as that of the time charter rate with respect to a second-hand ship which is usually available immediately. Its price should be the equivalent spot rate in shipping market. Then one would expect that the new-building ship price leads the second-hand ship price like the lead-lag relation between the time charter rate and the spot rate. Another point against the view that the new-building price adjusts to the second-hand ship price over time is from *Tsolakis et al.* (*2003*) and *Haralambides et al.* (*2004*). These authors argued that the driven factors are different for these two ship prices – the new shipbuilding is cost driven whereas the second-hand vessel is market driven. Then it is doubtful that the new-building price adjusts to the second-hand ship price. But none of the authors provided any test to verify their statements. In other words, the existence of a temporal lead-lag relationship between the new-building and second-hand ship prices is still an open question. There is a lack of research on which price (new-building or second-hand) responses to the new information more quickly.

The bulk shipping market comprises the dry bulk and tanker sectors, each with their own distinct economic structures (*Veenstra, 1999*). Therefore, some important questions regarding the lead-lag relationship between ship prices should be answered: Do the new-building and second-hand ship prices respond to the new information (unobservable events) simultaneously or is there any lead-lag relationship between them? If a lead-lag relationship exists, does the second-hand ship price or the new-building ship price lead? Are the lead-lag relationships in the dry bulk and tanker sectors identical or different, and why?

To answer these questions, it is considered two main shipping sectors – the dry bulk and tanker sectors. Various vessel sizes are considered separately to allow comparisons of the relationship between new-building and second-hand ship prices.

The first objective is to examine the existence of a lead-lag relationship between the new-building and the second-hand ship price in the dry bulk and tanker sectors. Which price can be used as an indicator (response to the new information more quickly) in each sector is determined. The second objective is to compare and explain the results drawn from two shipping sectors in order to emphasize the differences and reveal the implications for ship investment decision on the new and second-hand vessels.

1.3.2 Relationships between the freight and ship markets

The second part is to study the temporal relationships between the freight and ship markets. There are few studies researched on the temporal linkage under three-variable framework.

It is well known that seaborne transport activities can cause the demand for ships by the cargo-owners. As discussed earlier, the cargo-owners will enter into a special contract with the ship-owners for the hire of their ships. The ship-owners may buy an old or order a new ship to get the ships. Any decision made by the ship-owners for how to get the ships will influence the ship markets (new-building and second-hand markets) immediately. Therefore, there are economic links between the market for the transportation services (freight market) and the markets for the ships. The economic links between the freight and ship markets are important to both cargo-owners and ship-owners, since clearly understanding of market relationships can help them in their chartering or investing strategy.

Veenstra (1999) has indicated the different economic structures for the dry bulk and tanker sectors. Specially, he verified this important difference and pointed out that the role of second-hand ship price or even the second-hand market maybe the reason. However, he did not provide any proof of this inference. Since his main concern is an integrated market model for the whole shipping industry, he used average quarterly data (from 1980 to 1995) rather than specific ship types.

Another problem in *Veenstra (1999)* is that he used order-book as the typical variable to represent the new-building market. As he used Structural Vector Autoregressive model, the linear relationship between the variables is the underlying assumption. However, linear or non-linear relationships between the order-book, freight rate and the second-hand ship price are unknown to us. First, the second-hand ship price can be viewed as a discount new-building price under some normal circumstance. Second, researchers in the past suggested that the expected future time charter rates could be viewed as current second-hand ship price. Although the exact function between the three variables is unknown, at least the linear relationship between them is more possible. In shipping industry, since the movable capital assets are traded, ship prices over time are of great importance to investors making decisions. Thus, using new-building ship price instead of order-book as the key variable to represent the new-building market seems more reasonable. To this end, the new-building and second-hand ship prices are chosen as the typical variables for the new-building and second-hand ship markets.

For the freight market, it has been established in the previous works that the time charter rate is the variable that channels information on freight market developments (*Haralambides et al. 2004, Tsolakis et al. 2003, Veenstra 1999*). Thus, time charter rate is chosen as a represented variable for the freight market.

Based on these discussions, the first objective of this part of research is to investigate the dynamic relationships between freight and ship markets in the dry bulk and tanker sectors. Research on this relation can provide insights on the directions of information flow and on how well these markets are linked. The investors will benefit from understanding the leading indicator in two shipping sectors. Research on the difference between the dry bulk and tanker sectors is important because if the temporal linkages between the freight and ship markets are different, the investment timing and strategies on ships in these two sectors would also be different.

1.4 Structure of the thesis

The organization of this thesis is as Figure 1-8:

Chapter 1 is a brief introduction of the background of this research. Since the issues concerned in this thesis consist two shipping sectors, three shipping markets and six ship segments (three segments in each sectors), the first Chapter is to give the background of these items. Meanwhile, as discussed above, one aim is to compare the similarity or differences between the dry bulk and tanker sectors, then the comparison is also made in this Chapter.

Chapter 2 deals with the literature of past works. The review is divided into three parts: first is the literature in the freight market, and second is devoted to the ship markets, last part is literature in the relationship between freight and ship markets.

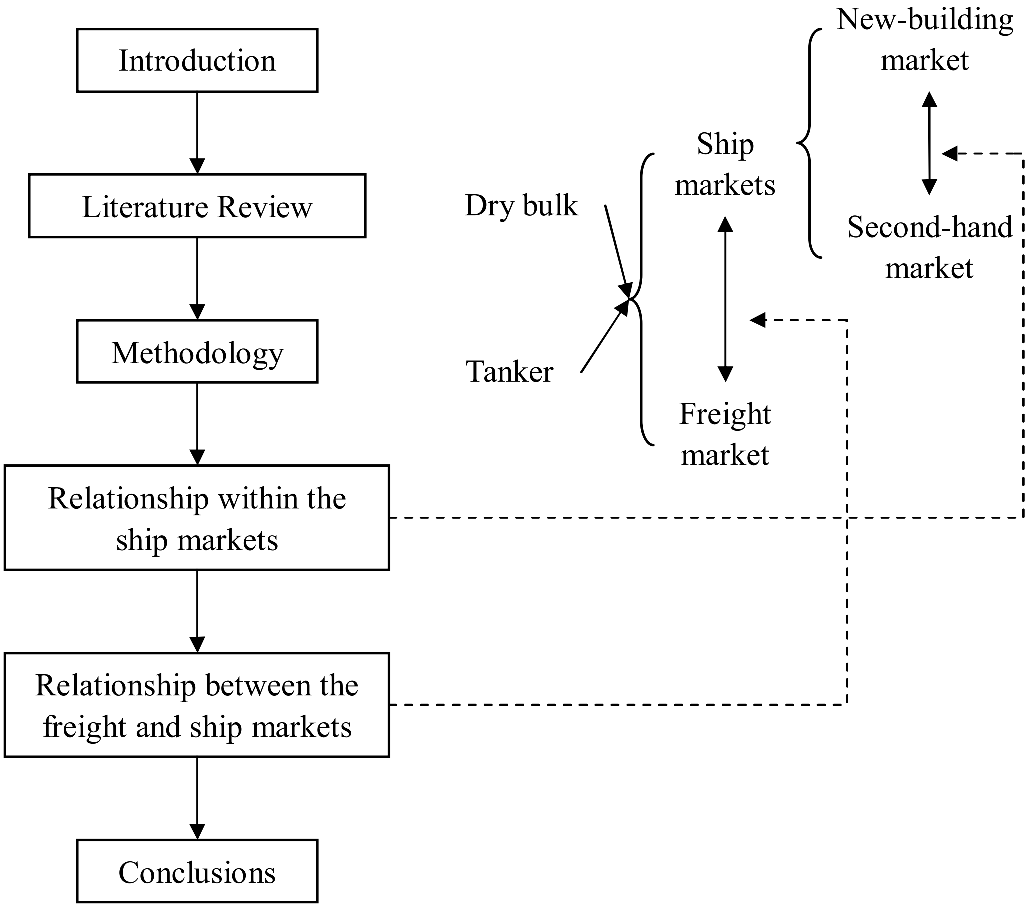
Chapter 3 contains the methodological framework used in this thesis. It describes a modelling strategy used time series techniques. The central method is to form the Vector Autoregressive (VAR) and Vector Error Correction (VEC) model which allows the analysis of the relationship between multivariate time series

Chapter 4 discusses the relationship between the new-building and second-hand ship prices. Whether these two prices are cointegrated and whether there exists a temporal lead-lag relationship between them are examined within two shipping sectors.

Chapter 5 extends the test in Chapter 4 to include another variable - time charter rate. Analysis in this Chapter is more complex than in Chapter 4. The test is carried out in the dry bulk and tanker sectors separately. Then the comparison is presented.

Finally, Chapter 6 represents the main conclusions and directions for the future research.

Figure 1-8: Structure of the Thesis



Chapter 2: Literature Review

The aim of this chapter is to review previous studies in analyzing the freight and ships markets. The first objective is overview the existing works. The second objective is to identify the gaps of past studies.

2.1 Literature in the freight market

Studies in the freight market have focused on the formation of the freight rate through a supply-demand framework (*Tinbergen 1934, Koopmans 1939, Hawdon 1978, Beenstock 1985, Beenstock and Vergottis 1993,* etc.), or the term structure between the spot and time charter rates (for example, *Zannetos 1966, Glen et al. 1981, Hale and Vanags 1989, Wright 2000, Kavussanos and Alizadeh 2002a, Kavussanos and Nomikos 2003*), or with modern techniques to forecast freight rate (*Veenstra 1997*).

The pioneering studies are conducted by *Tinbergen (1931, 1934)* and *Koopmans (1939)*. *Tinbergen* (*1931, 1934*) provided the first quantitative analysis of the shipbuilding and freight markets, respectively. *Koopmans (1939)* was the first attempt to conduct research distinguished the dry bulk and tanker sectors.

Tinbergen (1931) made the first attempt to make a link between the new-building and freight markets through three variables - freight rate, order-book and the fleet size. The results showed that the new-building industry follows a cyclical pattern with approximately 8-year duration from peak to peak.

Tinbergen (1934) focused on the investigation on the formation of the freight rate through a supply- demand framework. On the demand side, he assumed a perfectly inelastic demand for shipping services. On the supply side, the fleet size, freight rate and bunker price were considered as the factors. His results established that the freight rate is affected by the fleet size, demand and bunker price.

Koopmans (1939) is the first attempt in the literature that distinguished between the dry cargo and tanker sectors. He applied the models proposed by *Tinbergen (1931, 1934)* in the tanker sector. One notable contribution of this research is that he suggested the shape of the supply curve in tanker shipping.

Beenstock (1985, 1989a, 1989b) used conventional supply-demand framework to determine the spot rate in freight market. The supply side factors are the same as those in *Tinbergen (1934)*. However, the demand side is assumed to be related to freight rate and world trade.

Hawdon (1978) described two reduced form equations for the spot rate in the dry bulk and tanker sectors. Demand volumes, bunker price, spot rate in the other sector and fleet size were considered as the factors on spot rate.

Strandenes (1984) studied the relationship between the time charter rate and the second-hand ship price using annual data. She explained the second-hand price as a function of discounted earnings at current market and the market replacement value of the ship which was assumed to be equal to the corresponding new-building price.

Another research area in the freight market is the relationship between the spot and time charter rates. The rule that describes this relationship is called the term structure of freight rate. *Zannetos (1966)* is the first scholar to distinguish between the determinants of the spot and time charter rates. He pointed out that the time charter rate should be represented through a series of expected spot rates. However, he did not test his assumption.

Glen (1981) studied the relationship between the spot and time charter rates in the tanker sector. The results showed that time charter rate leads spot rate but not vice versa. The same findings have also been found in *Kavussanos and Nomikos (2003)*.

Hale and Vanags (1989), Veenstra (1999) and *Kavussanos and Alizadeh (2002a)* also proposed a present value model to formulate the relationship between the spot and time charter rates in the dry bulk sector. Their results do not support the validity of the term structure.

Veenstra (1997) used a Vector Error Correction (VEC) model to forecast the freight rate in the dry bulk sector. He chose three routes of freight rate in the Capesize and Panamax ship segments. He found that there are cointegrations among these 6 variables. So VEC model was used to forecast freight rate.

Since this thesis focused on the relationships among shipping markets, studies specialized in just freight market will not further reviewed.

2.2 Literature in the ship markets

The existing studies on the behavior of ship prices can categorized into three main groups. The first group uses the traditional approach to explore the determinants of ship prices among a number of variables such as order book, freight rates, bunker prices, scrapping prices, etc. under the supply-demand equilibrium (*Veenstra 1999, Tsolakis et al. 2003, Haralambides et al. 2004*) or disequilibrium (*Charemza and Gronicki 1981*) model. The early studies applied the capital asset theory to investigate the ship prices (*Strandenes 1984, Beenstock 1985, Beenstock and Vergottis 1989a, 1989b*). However, the research direction shifted after *Beenstock and Vergottis*. Many researchers noticed that the past studies did not take into account of the stochastic properties of the variables in using non-stationary data in models which may lead to the biased results. In more recent studies, time series techniques are used to investigate these determinants (*Tsolakis et al. 2003, Haralambides et al. 2004, Merikas et al. 2008*). In summary, these works consider the degree of impact of one variable on another, but the question of how fast these prices respond to the new information has not been examined.

Charemza and Gronicki (1981) considered a model which is notable for the fact that demand can be unequal to supply in the freight and ship markets in any given time period. This model was applied to both the dry bulk and the tanker sectors with using annual data, and the results implied that the freight market supply is influenced by the changes of the fleet size and freight rates either in the dry bulk or the tanker sectors.

Strandenes (1984) studied the relationship between the time charter rate and the second-hand ship price using annual data. She explained the second-hand price as a function of discounted earnings at current market and the market replacement value of the ship which was assumed to be equal to the corresponding new-building price.

Beenstock and Vergottis (1985, 1989a, 1989b) argued that the supply-demand framework is not appropriate for determining ship prices, since a ship is a real capital asset and therefore its price depends on expectations. *Beenstock (1985)* proposed a theoretical model in which the freight markets and ship markets are interdependent. He used portfolio theory to model ship prices and found that the current ship price is a function of the ship price last period, current and last period world trade activities and a weight average of the expected future world trade. *Beenstock and Vergottis* then published two papers outlining two separate models, one for dry cargo (1989a) and one for tankers (1989b). They distinguished between the new-building and second-hand markets and adopted an asset pricing modelling approach. Both models used the same theory of ship price determination as *Beenstock (1985)*. There are two basic hypotheses in their models: efficient second-hand market and the rational expectations hypothesis.

Tsolakis et al. (2003) used the Error Correction Model (ECM) to analyze second-hand ship prices in the tanker and dry bulk sectors under the supply-demand equilibrium model. The demand and supply sides for the second-hand ships are as follows:

$$Q_{SH}^{D} = f(fr, SH, NB, LIBOR)$$
$$Q_{SH}^{S} = f(O/F, SH)$$

Since $Q_{SH}^{D} = Q_{SH}^{S}$, then the second-hand ship prices can be expressed as: $SH = f(\overset{+}{fr}, \overset{+}{NB}, \overset{+/-}{O/F}, \overset{-}{LIBOR})$, where NB and SH mean the new-building and second-hand ship prices respectively; fr is the average time charter rate; O/F is the order book as a percentage of the total fleet and $LIBOR$ means interest rate.

Haralambides et al. (2004) extended *Tsolakis et al. (2003)*'s research to include both second-hand and new-building ship prices. They argued that the new-building and second-hand ship prices are not perfectly correlated as assumed in *Beenstock (1985)* since the new-building ship price does not react to the changing of market conditions as quickly as the second-hand ship price. Because building a new ship involves heavy investments and sunk costs. Their results showed that the new-building ship price and time charter rate have the greatest effect of all the variables on the second-hand ship price. However, the annual data they used limits the degree of freedom substantially when the Vector Autoregressive (VAR) or Vector Error Correction (VEC) model is used. Another question is they found that the new-building ship price is stationary in Handysize segment but not stationary in other ship segments. However, they still used different integrated orders of the series to test cointegration. Thus, results in dry bulk sector are not very trustable in this paper.

The second group of the research on ship prices focuses on the price formation in the second-hand ship market. It discusses whether this market is efficient and rational by testing the validity of the Efficient Market Hypothesis (EMH) (*Hale and Vanags 1992, Glen 1997, Kavussanos and Alizadeh 2002a*). These studies use 5-year-old second-hand ship price in each ship segment to test whether EMH holds in the second-hand ship market. The results are intended to show whether the changes of second-hand ship price in one ship segment can be used to improve the predictability of the second-hand ship price in another segment. This kind of information can be used in the decision on what kind of second-hand ship type should be purchased when the investment on second-hand ships need to be made.

Hale and Vanags (1992) applied the E-G two-step test of cointegration to examine the hypothesis of efficient second-hand dry bulk ship market. The efficient markets hypothesis says that in an efficient market, prices cannot be forecasted. Then there can be no long-run relations between the second-hand prices. They used a data set of second-hand prices for three ship categories of the dry bulk carriers. Their results reject the hypothesis of cointegration between the pairs of second-hand prices. However, they found one cointegration existed among all the three second-hand prices. From this, *Hale and Vanags* doubted about the efficient for second-hand ship markets.

Glen (1997) re-analyses and extended the earlier study of the efficiency properties of second-hand prices by *Hale and Vanags (1992)* using Johansen test of cointegration analysis in both the tanker and dry bulk sectors. *Glen (1997)* indicated that the existence of cointegration does not necessarily imply market efficiency. His results showed that some pairs of the prices in both the tanker and dry bulk sectors appeared to be cointegrated, which differ from *Hale and Vanags*' conclusion.

Kavussanos and Alizadeh (2002a) proposed a testing framework which investigated the validity of the EMH in the dry bulk sector. They questioned the test of EMH in *Hale and Vanags (1992)* and *Glen (1997)*. They argued that the existence of cointegrating relationship between price series just indicates that prices move together in the long-run but does not rule out the existence of excess profit making opportunities. So they used Vector Autoregressive models proposed by *Campbell and Shiller (1987)* to test the relationship between ship prices (including new-building, second-hand and scrap ship prices) and operating profits. Their evidences indicate that the EMH fails in the market for dry bulk ships.

The third group of the research on ship prices is related to the fluctuation of the price series over time. These studies aim to examine the properties of a single price series.

Kavussanos (1996, 1997) used the Autoregressive Conditional Heteroskedasticity (ARCH) model to examine the dynamics of volatilities in the dry bulk and tanker sectors. He found that asset values are more volatile for the larger vessels in both sectors, and the variances of second-hand vessel prices are time-varying and affected by factors such as time charter rate, interest rate and oil price. These variances reflect vessel price risks are themselves time-varying.

In conclusion, there is a lack of understanding on whether a lead-lag relationship exists between the new-building and second-hand ship prices, and if it exists, what it is and whether it is different for the dry bulk and tanker sectors. It is well known that the new-building and second-hand ship markets are interrelated; new information into one market may affect both prices. Investors who consider investing in new or second-hand ships will benefit from knowing which price can be viewed as a leading indicator. Thus, this part of work aims to fill a gap in the literature by studying the information transmission between the new-building and second-hand ship prices in both the dry bulk and tanker sectors so that they can be used in formulating investment strategies for investors and ship-owners.

2.3 Literature in the relationships between the freight and ship markets

Research on the relationships among the main shipping markets (four shipping markets), past studies generally paid their attentions to only two of them. For example, the relationships between the second-hand ship price and time charter rate (*Strandenes 1984, Alizadeh and Nomikos 2007*), or between the freight rate and new-building ship price (*Hawdon 1978, Xu et al. 2008*).

Alizadeh and Nomikos (2007) investigated the relationship between 5-year-old ship price and 1-year time charter rate in the dry bulk shipping sector. Results suggested that these two variables are cointegrated in every ship segment. Causality between them is from the time charter rate to second-hand ship price.

Xu et al. (2008) used panel cointegration to test the dynamic relationship between international sea freight rate and shipbuilding price in dry bulk market. She found that freight rate is sensitive to the shipbuilding price and they have a positive directional relationship in the dry bulk sector.

The studies analyzed the relationships among three markets are *Veenstra (1999), Tsolakis et al. (2003), Haralambides et al. (2004)* and *Lun and Quaddus (2009)*. *Tsolakis et al. (2003)* and *Haralambides et al. (2004)* have discussed above.

Lun and Quaddus (2009) found that the second-hand ship price is positively correlated with freight rate and the new-building ship price. But the relationship between new-building vessel price and freight rate is weakly significant. Actually, in reality, the new-building vessels often delivered after 2 to 3 years from ordering. So the effect of the new-building price may have a delay on freight rate.

Veenstra (1999) is the only researcher who mentioned and verified that the casual links between the main shipping markets are different in the dry bulk and tanker sectors. He presented a structural VAR model for the dry bulk and tanker shipping. This model consisted of five variables: order-book, trade flow, second-hand ship price, time charter rate and spot charter rate. His results indicated that the role of second-hand ship price differed in the dry bulk and tanker shipping sectors. However, he did not provide any test on this inference. It has been discussed earlier that the original intention of this study is to offer insights into the structure of the whole shipping industry. Then he investigated this issue with the average quarterly data from 1980 to 1995 in which only 60 observations contains, and he chose order-book rather than the new-building ship price as the key variable in the new-building market.

In summary, two gaps exist in the existing works. First, the investigations on the temporal relationships among three variables are very limited. The works on the differences for the dry bulk and tanker sectors are even insufficient. Second, the data used in the studies including three markets are either annual or quarterly data. The temporal relationships happen within three months can not be examined in their studies.

Therefore, the aim of this part is to examine the temporal links between the freight and ship markets with monthly data series. Then, the different linkages between the dry bulk and tanker sectors will be compared. The possible reasons caused the differences will be examined at last.

Chapter 3: Methodology

A classic regression model can not fully provide a dynamic specification among a number of variables. This problem can be solved by using the approach in time series. A time series is a sequence of data points that span a certain period. Then time series data have a natural temporal ordering. Time series models usually used to capture empirically relevant features of the observations.

3.1 The Vector Autoregressive model

For modelling the relationship among a small set of time series of interest, the vector autoregressive (VAR) model is a popular choice (*Lütkepohl 1991*). The VAR model is introduced into empirical economics by *Sims (1980)*. Applications of this model to financial issues are given in *Hamilton (1994), Cuthbertson and Nitzsche (1996), Campbell et al. (1997) and Tsay (2001)*. This model can be viewed as a system of reduced form equations in which each of the endogenous variables is regressed on its own lagged values. It can be used to analyze the dynamic impact of random disturbances on the system of variables. The mathematical presentation of basic q-lag VAR(q) is as follows:

$$Y_t = c + \Pi_1 Y_{t-1} + \Pi_2 Y_{t-2} + \cdots + \Pi_q Y_{t-q} + \varepsilon_t \qquad (1)$$

where Y_t is a k-dimensional vector of time series variables, Π_i are matrices of coefficients to be estimated, c is the intercept, q is the lag length and ε_t is an unobservable zero mean white noise vector process which can be also viewed as a vector of innovations. In the VAR model above, the vector of innovations ε_t is unanticipated but become parts of the information set in the next period. This implies that the residuals can capture the unobservable events.

The estimation of a VAR model is relatively simple. Since only lagged values of endogenous variables appear in VAR equations, the model can be estimated by ordinary least squares (OLS) (*Lütkepohl 1991*). However, in order to obtain unbiased estimates, the model requires all the variables in Y_t to be stationary. So in the next section, unit root test for stationarity will be introduced.

3.2 Unit root test

Stationarity is used as a tool in time series analysis. For a stationary series, its mean and auto-covariances of the series do not depend on time. And any series that is not stationary is said to be non-stationary. An example of a non-stationary series is the random walk:

$$y_t = y_{t-1} + \varepsilon_t \tag{2}$$

where y is the series and ε_t is a stationary term. The random walk is a difference stationary series because the first difference of y is stationary:

$$y_t - y_{t-1} = \varepsilon_t \tag{3}$$

A difference stationary series is said to be integrated and is denoted as $I(d)$ where d is the order of integration. The order d can be also called the number of unit roots contained in the series. Therefore, a stationary series is $I(0)$. And if there is one unit root, the series is satisfied $I(1)$ process. In the existing research, ship price series are often found non-stationary in log-levels but stationary in their first differences (i.e., the $I(1)$ process) either in dry bulk or tanker sector (*Kavussanos 1996, Glen 1997, Veenstra 1999, Kavussanos and Alizadeh 2002a, Alizadeh and Nomikos 2007*). However, since the data samples used in this paper are not exactly the same as those in the past research, the stationarity of each series is still need to be tested with using both the Augmented Dickey-Fuller (ADF) (*Dickey and Fuller 1981*) and the Phillips and Perron (PP) (*Perron 1988, Phillips and Perron 1988*) methods.

3.3 Cointegration test

From results of the past research, it is known that the price series in this study are likely to be non-stationary and follow I(1) process. One method to overcome this problem is to transfer the series into stationary series by taking first differences. But this approach would take away the long-run relationship between variables and lose useful information. If a set of series will move together over time, it implies that these series are driven by a common stochastic trend. In this case, they have a long-run relationship. One definition of the long-run employed in econometrics implies that the variables have converged upon some long-term values and are no longer changing. Variables are called cointegrated if they have a long-run relation. *Engle and Granger (1987)* pointed out that the non-stationary time series are cointegrated if the linear combination of the series is stationary. If cointegrated relation exists in the VAR model, Vector Error Correction (VEC) model which can be viewed as a cointegrated VAR model could be considered to apply.

There are three ways to test the existence of cointegration among a number of variables.

One is called Engle-Granger two-step method (*Engle and Granger 1987*). It is generally applied in the system contained two variables. The Engle-Granger two-step method is a residual based approach with a single equation. The model is $y_t = c + \beta_1 x_t + u_t$, where x_t and y_t are variables, c is the intercept and u_t is the residual. Step one is to make sure that all the individual variables satisfy the $I(1)$

process and then estimate this regression model using the OLS method. Step two is to test the stationarity of the residual series $\hat{u}_t$. If $\hat{u}_t$ satisfies $I(0)$, x and y are cointegrated. If $\hat{u}_t$ is I(1), x and y are not cointegrated. One notable problem of using the Engle-Granger two-step method is the stationary test on the residual. The critical values are changed comparing with an ADF test on a series of raw data and Eviews does not give us these changed critical values. So the changed critical values used here are from *MacKinnon (1991)*.

Another method is Johansen cointegration test (*Johansen 1988, 1991*). It can be used in a VAR model containing more than two variables. *Shintani* (*1994*) found that the Johansen procedure has a greater power than Engle-Granger two-step method in testing for cointegration.

The Johansen co-integration test is usually used together with the VAR model. A VAR model containing co-integrated variables can be also called vector error correction (VEC) model. A VEC model is a restricted VAR for non-stationary series that are known to be co-integrated. The general VEC model is written as

$$\Delta Y_t = c + \Pi Y_{t-q} + \sum_{i=1}^{q} \Gamma_i \Delta Y_{t-i} + \varepsilon_t \qquad (4)$$

In this model, the Γ_i's are often referred to as the short-run parameters while the matrix Π contains the components of the long-run co-integration relations, if they exist. Johansen test focuses on the examination of the matrix Π which can be interpreted as a long-run coefficient matrix.

The test for cointegration in Y_t is performed by calculating the rank of the Π matrix. There are three possibilities for this rank: it can be zero, indicating no co-integration relations; it can be equal to the total number of components, indicating stationary of all time series in the model; and finally, it can also be r rank between zero and the total number of components, and in this case, there are r co-integrating vectors in Y_t.

Johansen (*1988, 1991*) proposed trace statistic (λ_{trace}) and maximum eigenvalue statistic (λ_{max}) to determine the rank of Π. Once the rank is determined, Π can be decomposed into two matrix $\alpha\,(n\times r)$ and $\beta\,(n\times r)$, where $\Pi = \alpha\,\beta'$. Matrix β' contains r linearly independent rows and the product of β' and Y_t gives r stationary long-run relationships. Matrix α is known as the adjustment parameters which contain the weights attached to the cointegrated relations.

Another test of existence of cointegration is proposed by *Saikkonen and Lütkepohl*

(*2000a, b, c*) (S&L test). This test proceeds by estimating the deterministic term (such as an intercept or a linear trend term) with GLS procedure first. Then subtracting is from the observations and applying a Johansen type test to the adjusted series. This test will be carried out in JMulTi software[11].

In this thesis, *Johansen* technique will be applied as the primary tool for exploring the existence of cointegration. When the results from λ_{trace} and λ_{max} statistics are contrast with the existence of co-integration at 5% significant level (e.g. λ_{trace} suggests cointegration exists but λ_{max} favors cointegration does not exist), for the two-variable system, the Engle-Granger two-step method will be employed to double check the existence of co-integration, while S&L test will be applied in the model of three variables.

3.4 Order selection

Either VAR or VEC model needs to determine the lag order q first. A reasonable lag length is important to the results from VAR. In general, it is better to use more rather than fewer lags, since the theory is couched in terms of the relevance of all past information. However, more unknown parameters need to be estimated if the time lag length is larger. Then a proper balance should be kept for the lag length

[11] Refer to the Website: www.jmulti.com

Lütkepohl (1991).

In this thesis, the order criterion by *Schwarz (1978)* (SC) and Akaike's Information Criterion (AIC) will be employed. However, the lag length criteria do not suggest the same choice in one model occasionally. *Lütkepohl* (*1991*) found that the lag length selected by these two criteria has the following relations $q(\text{SC}) \leq q(\text{AIC})$. If $q(\text{SC}) = q(\text{AIC})$, this lag length will be applied directly. Otherwise, the optimal lag length between $q(\text{SC})$ and $q(\text{AIC})$ will be examined by a range of tests on analyzing the residual auto-correlation (e.g. Portmanteau test, Breusch-Godfrey test and ARCH-LM test) (*Lütkepohl and Krätzig 2004*). In principle, it's better to choose the one which makes the residual auto-correlation less significant. In the cases that residuals generated from $q(\text{SC})$ and $q(\text{AIC})$ are both non-significantly auto-correlated, $q(\text{SC})$ is chosen because too large lag length is not recommended for the VAR model (*Lütkepohl 1991*).

3.5 Granger causality test

The Granger causality approach to the question of whether x causes y is to see how much of the current x can be explained by past values of y, and then to see whether adding lagged values of x can improve the explanation. If x helps in the prediction of y or equivalently if the coefficients on the lagged x's are statistically significant, y is said to be Granger caused by x. It is important to note that the statement "*x* Granger causes *y*" does not imply that *y* is the effect or the result of *x*, it only means a correlation between current value of one variable and the past value of others. Granger causality measures precedence and information content but does not by itself indicate causality in the more common use of the term.

Granger causality test in the VAR framework will use to capture the dynamic linkage among a number of variables. However, Granger causality test based on OLS estimation in VAR model with the level data series is not recommended (*Toda and Phillips 1993*). Therefore, the existence of cointegration should be controlled first.

If there is no cointegration, *Toda and Phillips* (*1993*) suggested that the causality test on the VAR model using the stationary difference data series is likely to have a higher power than using the level data series directly for finite samples. Therefore, the VAR model formulated in terms of the first difference data series will be applied. The bivariate VAR model of the first difference data are estimated with

$$\begin{aligned} \Delta x_t &= c_1 + \sum_{j=1}^{q} \alpha_{1j} \Delta x_{t-j} + \sum_{i=1}^{q} \beta_{1i} \Delta y_{t-i} + \varepsilon_{1t} \\ \Delta y_t &= c_2 + \sum_{j=1}^{q} \alpha_{2j} \Delta y_{t-j} + \sum_{i=1}^{q} \beta_{2i} \Delta x_{t-i} + \varepsilon_{2t} \end{aligned} \tag{5}$$

where Δx_t and Δy_t denote the variables for the first difference. $\varepsilon_t = (\varepsilon_{1t}, \varepsilon_{2t})'$ is the vector of the corresponding error terms which contain all the other information that may affect x and y, and q is the optimal lag length.

If cointegration does exist, Granger causality test based on the VEC model will be adopted instead of using the first difference data based on VAR model. The Granger causality test based on the VEC model can be expressed as:

$$\begin{aligned}\Delta x_t &= c_1 + \sum_{j=1}^{q} \alpha_{1j} \Delta x_{t-j} + \sum_{i=1}^{q} \beta_{1i} \Delta y_{t-i} + \delta_1 ECT_{t-1} + \varepsilon_{1t} \\ \Delta y_t &= c_2 + \sum_{j=1}^{q} \alpha_{2j} \Delta x_{t-j} + \sum_{i=1}^{q} \beta_{2i} \Delta y_{t-i} + \delta_2 ECT_{t-1} + \varepsilon_{2t}\end{aligned} \quad (6)$$

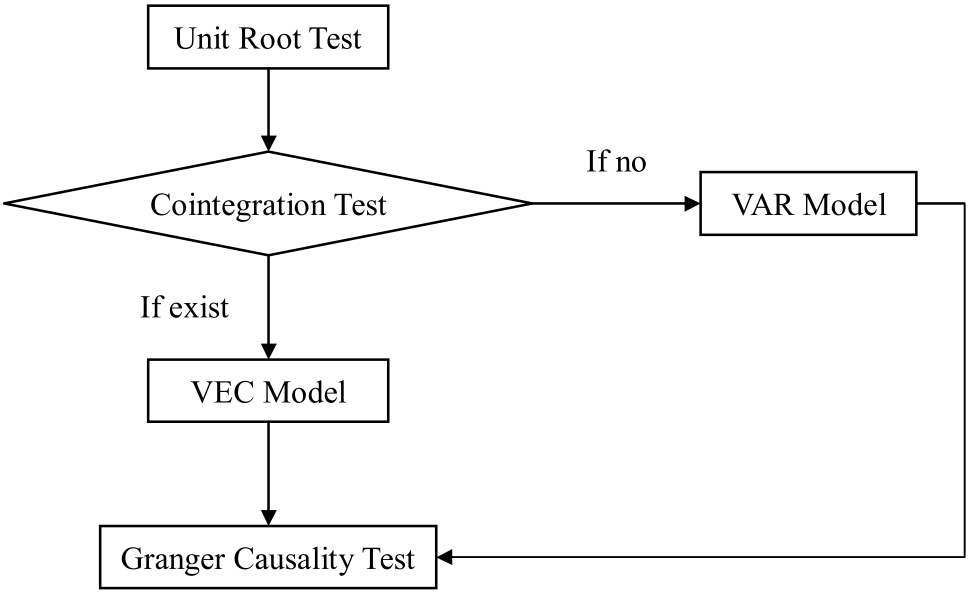
Compared with equation (5), (6) has an additional term ECT_{t-1} with coefficient δ. ECT_{t-1} is known as the error correction term and contains information on the long-run relationship between cointegrated variables since the deviation from long-run equilibrium is corrected gradually through a series of partial short-run adjustments.

Thereafter, the Granger causality test examines the null hypothesis that $\beta_{1i} = 0$ or $\alpha_{2j} = 0$ for all i and j (i, j=1, 2… q) in both (5) and (6). When $\beta_{1i} = 0$, the null hypothesis is that y does not Granger cause x in the first regression in (5) and (6). When $\alpha_{2j} = 0$, the null hypothesis is that x does not Granger cause y in the second regression in (5) and (6). Thus, evaluation of the significance of variables in VAR should be conducted.

3.6 Analyzed methods

Overall, the analyzed methods consist of five steps. First, for a set of variables, ADF and PP tests are used to examine the stationarity of each series. Second, if they are all non-stationary, Johansen cointegration test will be applied to check if there is cointegration among variables. In this step, if a VAR model contains only two variables, Engle-Granger two-step method is used to double check the results. If the model contains three variables, S&L test is adopted. After confirming the existence of cointegration, the third step is to formulate and estimate VAR or VEC model. Then, Granger causality test based on either VAR or VEC will be applied to examine the temporal linkage among the variables. The structure of the methods used in this thesis is shown in Figure 3-1.

Figure 3-1: The Analyzed Methods in This Thesis



Chapter 4: Relationships within the Ship Markets

4.1 Data analysis

The data used in this part consists of monthly new-building, 5-year-old and 10-year-old second-hand ship prices for three different-size carriers in both dry bulk and tanker sectors. The data are collected from Clarkson Research Services Limited 2010 and Lloyd's Shipping Economist. All prices are quoted in million dollars. For convenience, the notation *NP* denotes the new-building ship price, and *FP* and *TP* denote the 5-year-old and 10-year-old second-hand ship prices, respectively.

The logarithmic transformation is used for all the data series. There are three reasons why log transforms. First, taking a logarithm can often help to rescale the data so that their variance is more constant, which overcomes a common statistical problem. Second, logarithmic transforms can help to make a positively skewed distribution closer to a normal distribution. Third, taking logarithms can also be a way to make a non-linear, multiplicative relationship between variables into a linear, additive one.

The categories of the ship segments in each sector are the same as in most studies in the past (*Kavussanos 1996, 1997, Tsolakis et al. 2003, Haralambides et al. 2004, Alizadeh and Nomikos 2007*): for the dry bulk sector, three segments will be concerned, namely Capesize, Panamax and Handysize bulk carriers; for the tanker sector, VLCC, Suezmax and Aframax tankers are divided.

The data used in this paper are collected as early as they are available to avoid covering only part of a shipping cycle (*Kavussanos and Alizadeh 2002b*). Specifically, data samples are from Jan. 1976 to Oct. 2008 except the Capesize prices are from Oct. 1983 to Oct. 2008, the VLCC prices are from Jan. 1992 to Oct. 2008 and the Suezmax prices are from Jan. 1981 to Oct. 2008. Nevertheless, the ship type classification for the world merchant fleet has changed over the years. The new-building and second-hand price series do not always match with their deadweight classification. To this end, the data from Clarkson are mainly used and adjustments had been made to the data series by comparing Clarkson quotations with Lloyd's.

First step is to describe and plot the data. From the table and graph, it can be obtained a first indication of the structure in the data. From Table 4-1, it can be clearly observed that the mean of the new-building price is higher than the 5-year-old second-hand ship price and 10-year-old second-hand ship price is higher than 5-year-old second-hand ship price most of the time. The skewness statistic summarizes the degree and direction of asymmetry in the distribution of the variable. A symmetric distribution has a skewness statistic of 0. A negative value means skewed to the left while a positive value indicates the distribution skewed to the right. So the distribution of ship prices in the dry bulk sector are all skewed to the right and left skewness often occurs in the tanker sector. This difference of ship price series gives us the first impression that the structures of these two sectors are different. The Kurtosis statistic is a summary of the shape of the distribution. A normal distribution has a kurtosis of 3. If the value is less than 3 then the distribution is flatter than a normal distribution, with a lower peak and heavier or wider tails. From the results in Table 4-1, the price series are all platykurtic in the tanker sector and 5-year-old second-hand ship prices are all leptokurtic in the dry bulk sector but the other price series in the dry bulk sector are uncertain.

Table 4-1: Descriptive Statistics of the Ship Prices

Ship type	Variables	Mean	*S.D.*	*Skew.*	*Kurt.*
Capesize	*NP*	3.741388	0.270358	0.820298	3.265955
	FP	3.416780	0.513445	0.680109	4.027471
	TP	3.284969	0.602061	1.110734	2.969876
Panamax	*NP*	3.198326	0.304331	0.201441	2.800969
	FP	2.846756	0.577380	0.514806	3.630569
	TP	2.944519	0.570125	1.052089	3.074108

Table 4.1: Descriptive Statistics of the Ship Prices (Continued)

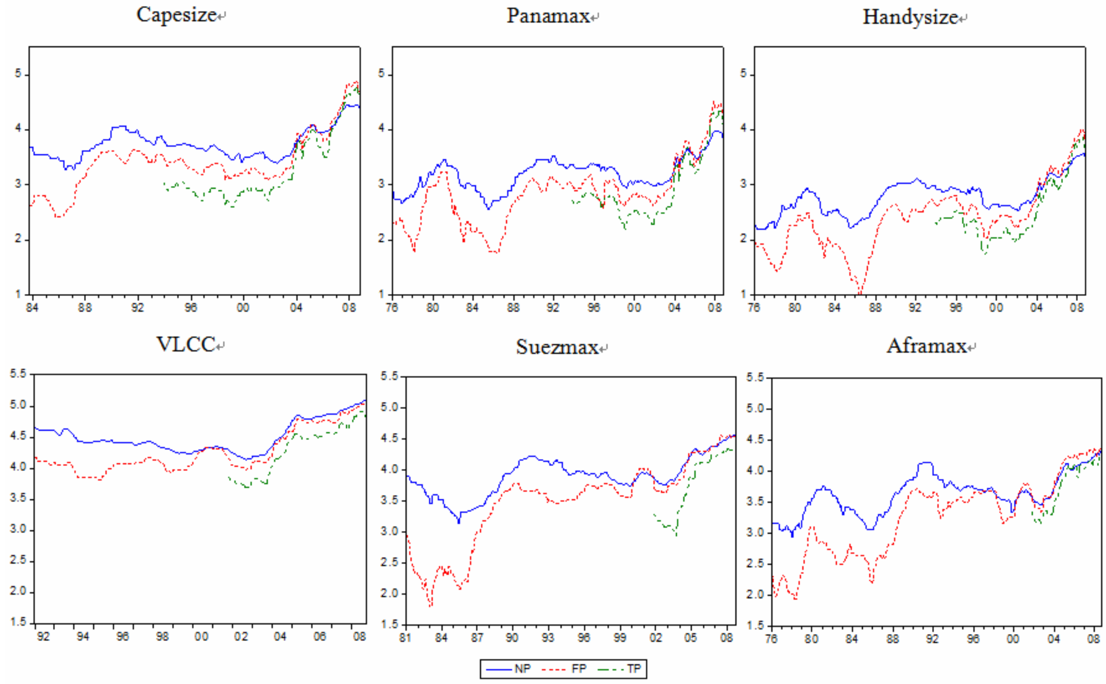
Handysize	*NP*	2.772745	0.318648	0.209861	2.696367
	FP	2.387706	0.596325	0.301628	3.382622
	TP	2.527968	0.546807	0.958767	2.962824
VLCC	*NP*	4.500448	0.248678	0.703153	2.395043
	FP	4.259894	0.337073	0.872168	2.426911
	TP	4.306075	0.395299	-0.297824	1.640926
Suezmax	*NP*	3.903903	0.316276	-0.132859	2.619725
	FP	3.481083	0.684060	-0.736159	2.741618
	TP	3.783607	0.499004	-0.355455	1.446459
Aframax	*NP*	3.638257	0.327095	-0.022398	2.375601
	FP	3.265316	0.637781	-0.217650	2.151140
	TP	3.780909	0.380759	-0.417019	1.484309

Notes:

1. *NP*, *FP* and *TP* represent the new-building, 5-year-old and 10-year-old second-hand ship prices respectively.
2. *S. D.* means the standard deviation of a data set. *Skew.* and *Kurt.* are skewness and kurtosis statistics.

Figure 4-1 plots *NP*, *FP* and *TP* of six types of carriers this thesis concerned. It can be observed these three price series exhibit the same long-run trend. The spreads between *NP* and second-hand ship prices (*FP* and *TP*) are larger in the tanker sector than in the dry bulk sector in the early stage while they are tied more closely in the tanker sector than in the dry bulk sector in more recent periods. In addition, the second-hand ship prices exceed the new-building ship prices in some periods, especially after 2004 for all ship types in the dry bulk sector. Consequently, the more recent periods can be viewed as the expansion periods for the shipping industry.

Figure 4-1: Time Series of the Ship Prices



Note: *NP*, *FP* and *TP* represent the new-building, 5-year-old and 10-year-old second-hand ship prices respectively.
Data source: Clarkson Research Services Limited 2010 and Lloyd's Shipping Economist

In this thesis, techniques in time series are applied to capture the dynamic temporal relationship between ship prices. In order to fit a time series model to the random variables, the variables should be stationary or co-integrated of order 0. The Augmented Dickey Fuller (ADF) and Phillips and Perron (PP) tests are used to check the stationary of the relevant data series. For the ADF and PP tests, the null hypothesis is that the original series is non-stationary (has a unit root). If the absolute values are smaller than the reported critical values, the null hypothesis of a unit root is accepted. Then the tested series is non-stationary. Otherwise, the hypothesis is rejected if the statistics are larger in absolute values than the critical values.

Results in Table 4-2 suggest that *NP, FP* and *TP* are all non-stationary in log-levels but are stationary in their first difference values in both the dry bulk and tanker sectors at 5% level. These results also mean that the ship price series satisfy the *I*(1) process.

Table 4-2: ADF and PP Test Results for the Ship Prices

Ship type	Variables	ADF	Type	PP	Critical value (5%)
Levels					
Capesize	*NP*	-0.131897	(C,0,1)	-0.364712	-2.870996
	FP	-0.235318	(C,0,1)	-0.321393	-2.870996
	TP	-1.690564	(C,T,1)	-1.600545	-3.435413
Panamax	*NP*	-0.907287	(C,0,1)	-0.859736	-2.868694
	FP	-0.690136	(C,0,1)	-0.830913	-2.868694
	TP	-0.258160	(C,0,1)	0.063178	-2.877636
Handysize	*NP*	-0.985687	(C,0,2)	-0.783452	-2.868713
	FP	-0.740436	(C,0,2)	-0.464554	-2.868713
	TP	-0.859907	(C,T,0)	-1.048217	-3.435269
VLCC	*NP*	-0.841688	(C,T,2)	-0.731209	-3.432566
	FP	-1.862470	(C,T,1)	-1.945324	-3.432452
	TP	-0.258523	(C,0,0)	-0.400469	-2.896779
Suezmax	*NP*	-1.518592	(C,T,1)	-1.750908	-3.423418
	FP	-2.214154	(C,T,1)	-2.430458	-3.423418
	TP	-0.457393	(C,0,0)	-0.461979	-2.896779
Aframax	*NP*	-0.889905	(C,0,2)	-0.919509	-2.868713
	FP	-3.034082	(C,T,3)	-2.668768	-3.421388
	TP	-0.594116	(C,0,0)	-0.624383	-2.896779

Table 4.2: ADF and PP Test Results for the Ship Prices (Continued)

First Differences					
Capesize	ΔNP	-13.88446**	(C,0,0)	-14.21853**	-2.870996
	ΔFP	-13.17962**	(C,0,0)	-13.17778**	-2.870996
	ΔTP	-9.343734**	(C,0,0)	-9.529097**	-2.877729
Panamax	ΔNP	-15.35463**	(C,0,0)	-15.51287**	-2.868694
	ΔFP	-14.55310**	(C,0,0)	-15.02577**	-2.868694
	ΔTP	-8.725835**	(C,0,0)	-8.703093**	-2.877636
Handysize	ΔNP	-10.77573**	(C,0,1)	-16.77722**	-2.868713
	ΔFP	-9.548469**	(C,0,1)	-13.94218**	-2.868713
	ΔTP	-11.33381**	(C,0,0)	-11.53702**	-2.877729
VLCC	ΔNP	-5.978644**	(C,T,1)	-10.47262**	-3.432566
	ΔFP	-11.06056**	(C,T,0)	-11.46630**	-3.432452
	ΔTP	-7.609015**	(C,0,0)	-7.703274**	-2.897223
Suezmax	ΔNP	-15.06123**	(C,T,0)	-16.10313**	-3.423418
	ΔFP	-12.87988**	(C,0,0)	-13.60806**	-2.870031
	ΔTP	-8.842151**	(C,0,0)	-8.841240**	-2.897223
Aframax	ΔNP	-10.67822**	(C,0,1)	-17.72884**	-2.868713
	ΔFP	-13.17202**	(C,0,0)	-13.73317**	-2.868694
	ΔTP	-8.018516**	(C,0,0)	-7.979195**	-2.897223

Notes:

1. *NP*, *FP* and *TP* represent the new-building, 5-year-old and 10-year-old second-hand ship prices respectively.
2. Δ stands for the first difference value.
3. (C, T,*) represents (constant, trend, lagged order)
4. Critical values are based on ADF test
5. ** denotes the statistical significance is at 1% level.

4.2 Relationships between the new-building and 5-year-old ship prices

Fist, the lead-lag relationship test between *NP* and *FP* is carried out. As discussed earlier in Chapter 3, co-integration analysis specifically addresses the non-stationary problem. Controlling for co-integration is necessary as it affects the specification of the model used for causality testing (*Bekiros and Diks 2008*). In this sub-section, *Johansen* (*1988*) technique will be applied. Furthermore, when λ_{trace} and λ_{max} statistics suggest contradictory results of the existence of co-integration at 5% significant level, the Engle-Granger two-step method will be employed to double check the existence of co-integration.

The estimation results are summarized in Table 4-3. Results of the optimal lag lengths for all the ship types are shorter than 3, which mean that the lead-lag relations between *NP* and *FP* will be considered within three month. The null hypothesis here is no co-integration (r=0) and at most one co-integration ($r \leq 1$) between *NP* and *FP*. From Table 4-3, it can be found that *NP* and *FP* are cointegrated in the Capesize and Panamax ship segments in the dry bulk sector while cointegration only exists in the Suezmax segment of the tanker sector. The failure of being cointegrated in some ship segments suggests that *NP* and *FP* may be driven by different trends especially for the tankers. It implies that the new and second-hand ships may not be viewed as close substitutes. The null hypothesis here is no cointegration (r=0) and at most one co-integration ($r \leq 1$) between *NP* and *FP*.

Table 4-3: Cointegration Test Results between *NP* and *FP*

Ship type	Lags	H_0	$\lambda_{\max}$	0.05 Critical Value	Prob.	λ_{trace}	0.05 Critical Value	Prob.
Capesize	q=2	r=0	18.7082	14.265	0.0093**	18.8021	15.495	0.0153*
		$r\leq 1$	0.09397	3.8415	0.7592	0.09397	3.8415	0.7592
Panamax	q=3	r=0	16.1201	14.265	0.0252*	17.5797	15.495	0.0239*
		$r\leq 1$	1.45963	3.8415	0.2270	1.45963	3.8415	0.2270
Handysize	q=3	r=0	10.7497	14.265	0.1672	11.4995	15.495	0.1826
		$r\leq 1$	0.74980	3.8415	0.3865	0.74980	3.8415	0.3865
VLCC	q=3	r=0	7.06002	14.265	0.4821	7.44640	15.495	0.5263
		$r\leq 1$	0.38638	3.8415	0.5342	0.38638	3.8415	0.5342
Suezmax	q=2	r=0	15.5740	14.265	0.0309*	19.3741	15.495	0.0123*
		$r\leq 1$	3.80006	3.8415	0.0512	3.80006	3.8415	0.0512
Aframax	q=3	r=0	7.45386	14.265	0.4369	9.21707	15.495	0.3457
		$r\leq 1$	1.76322	3.8415	0.1842	1.76322	3.8415	0.1842

Notes: * indicates statistical significance at 5% level; ** indicates significance at 1% level.

After testing of co-integration, Granger causality test will be used to investigate the lead-lag relationship between *NP* and *FP*. As discussed earlier, this test requires the stationary data series in the VAR model or the cointegrated variables in the VEC model. Therefore, based on the above results in Table 4-3, the VEC model will be used in the Capesize, Panamax and Suezmax ship segments for their *NP* and *FP* have a long-run relationship, and the VAR model on the first difference price series will be used to the other ship categories. The testing results are showed in Table 4-4.

Table 4-4 summarized the χ^2-statistic of the non-causality hypothesis. Figure 4-2 exhibits the lead-lag relationships between *NP* and *FP*, with the solid line indicating

Granger causality at 1% significant level and the dashed line indicating Granger causality at 5% significant level.

Table 4-4: Granger Causality Test Results between *NP* and *FP*

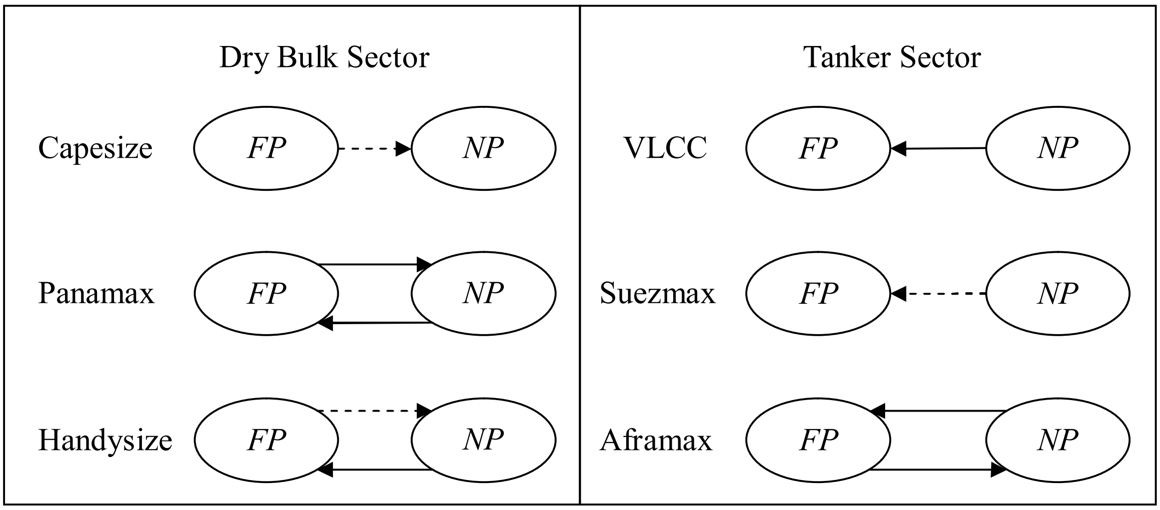
Segments	Lags	Non-causality Hypothesis	χ^2 statistics	*p*-value
Capesize	q=1	*FP* does not Granger cause *NP*	$\chi^2(1)$=5.726511	0.0167*
		NP does not Granger cause *FP*	$\chi^2(1)$=0.205509	0.6503
Panamax	q=2	*FP* does not Granger cause *NP*	$\chi^2(2)$=10.25307	0.0059**
		NP does not Granger cause *FP*	$\chi^2(2)$=12.83460	0.0016**
Handysize	q=2	*FP* does not Granger cause *NP*	$\chi^2(2)$=8.806857	0.0122*
		NP does not Granger cause *FP*	$\chi^2(2)$=12.64140	0.0018**
VLCC	q=2	*FP* does not Granger cause *NP*	$\chi^2(2)$=2.400515	0.3011
		NP does not Granger cause *FP*	$\chi^2(2)$=20.16530	0.0000**
Suezmax	q=1	*FP* does not Granger cause *NP*	$\chi^2(1)$=0.002144	0.9631
		NP does not Granger cause *FP*	$\chi^2(1)$=5.756185	0.0164*
Aframax	q=2	*FP* does not Granger cause *NP*	$\chi^2(2)$=11.27747	0.0036**
		NP does not Granger cause *FP*	$\chi^2(2)$=16.00320	0.0003**

Notes:
1. *NP* and *FP* are to represent the new-building and 5-year-old second-hand ship prices respectively.
2. * indicates statistical significance at 5% level; ** indicates significance at 1% level.

Considering the results in Table 4-4 and Figure 4-2, it can be concluded that the general lead-lag relationships between *NP* and *FP* in the dry bulk and tanker sectors are different. More specifically, in the dry bulk sector, the causality from *FP* to *NP* exists in the Capesize segment, while the bi-directional causality exists in the Panamax and Handysize segments at 5% level. However, the results from the tanker sector show the opposite relation for the VLCC and Suezmax ship segments, namely

NP significantly leads *FP*. For the Aframax ship segment, a two-way causality can be found. In summary, the lead-lag relationships between the new- building and 5-year-old second-hand ship prices are different for different ship types. Particularly, a causal relationship from the new-building price to the 5-year-old second-hand price is found for the tanker sector. This result contradicts the view from the past research. The view that the new-building price should adjust to the second-hand price over time is not supported by the data of 5-year-old second-hand prices in the tanker sector.

Figure 4-2: Lead-lag Relationships between *NP* and *FP*



Notes:
1. *NP* and *FP* are used to represent the new-building and 5-year-old second-hand ship prices respectively.
2. The solid line indicates that Granger causality is significant at 1% level, while the dashed line indicates that Granger causality is significant at 5% level.
3. Lead-lag relationships are based on the results in Table 4-4.

4.3 Relationships between the new-building and 10-year-old ship prices

The same test with 10-year-old second-hand price series is conducted next. With the earliest available 10-year-old second-hand ship prices, the sample sizes with 84 observations (sample periods are all from Nov. 2001 to Oct. 2008) for the tanker sector are obtained. The starting time points of data samples in the dry bulk sector are different. The price for 10-year-old Capesize bulk carriers covers a period from Jan. 1994 to Oct. 2008. For Panamax carriers, this sample period is from Nov. 1993 to Oct. 2008, and for Handysize carriers it is from Dec. 1993 to Oct. 2008.

All the 10-year-old price series are non-stationary in log-levels but are stationary in their first difference values as shown in Table 4-2. Table 4-5 summarizes the cointegration results between *NP* and *TP*. The λ_{trace} and λ_{max} statistics are inconsistent in the Panamax ship segment. So the Engle-Granger two-step test in this ship segment (Panel B in Table 4) is conducted. The results suggest that *NP* and *TP* are cointegrated only in the VLCC ship segments. The cointegration results of 10-year-old ship price are different from that of 5-year-old ship price. It indicates that the new-building ship price tied more closely with 5-year-old second-hand ship price than with 10-year-old ship price.

Table 4-5: Cointegration Test Results between *NP* and *TP*

Panel A: Johansen test								
Ship type	*Lags*	H_0	$\lambda_{\max}$	0.05 Critical Value	Prob.	λ_{trace}	0.05 Critical Value	Prob.
Capesize	q=2	r=0	11.0905	14.265	0.1497	11.1139	15.495	0.2046
		$r\leq 1$	0.02339	3.8415	0.8784	0.02339	3.8415	0.8784
Panamax	q=2	r=0	14.9545	14.265	0.0388*	15.2522	15.495	0.0544
		$r\leq 1$	0.29774	3.8415	0.5853	0.29774	3.8415	0.5853
Handysize	q=2	r=0	14.0531	14.265	0.0539	14.0553	15.495	0.0814
		$r\leq 1$	0.00225	3.8415	0.9602	0.00225	3.8415	0.9602
VLCC	q=3	r=0	21.2191	14.265	0.0034**	21.8858	15.495	0.0047**
		$r\leq 1$	0.66664	3.8415	0.4142	0.66664	3.8415	0.4142
Suezmax	q=2	r=0	7.77928	14.265	0.4016	7.94803	15.495	0.4710
		$r\leq 1$	0.16875	3.8415	0.6812	0.16875	3.8415	0.6812
Aframax	q=2	r=0	11.8400	14.265	0.1168	11.8864	15.495	0.1625
		$r\leq 1$	0.04642	3.8415	0.8294	0.04642	3.8415	0.8294

Panel B: Engle-Granger two-step test				
Ship type	Levels of residual (ADF test)	Observations	0.01 Critical Value	0.05 Critical Value
Panamax	-3.071101	180	-3.95	-3.37

Notes:

1. * indicates statistical significance at 5% level; ** indicates statistical significance at 1% level.
2. Critical values for the Engle-Granger two-step test are from *MacKinnon (1991)*.

The Granger causality test results between *NP* and *TP* are showed in Table 4-6. Figure 4-3 summarizes the lead-lag relationships between these two variables. For the dry bulk sector, causality from *TP* to *NP* can be found for all the ship segments. The opposite is true for the tanker sector, i.e., a one-way causality from *NP* to *TP* exists for all ship segments in the tanker sector. To conclude, the lead-lag relationships between *NP* and *TP* have not changed for the Capesize, VLCC and

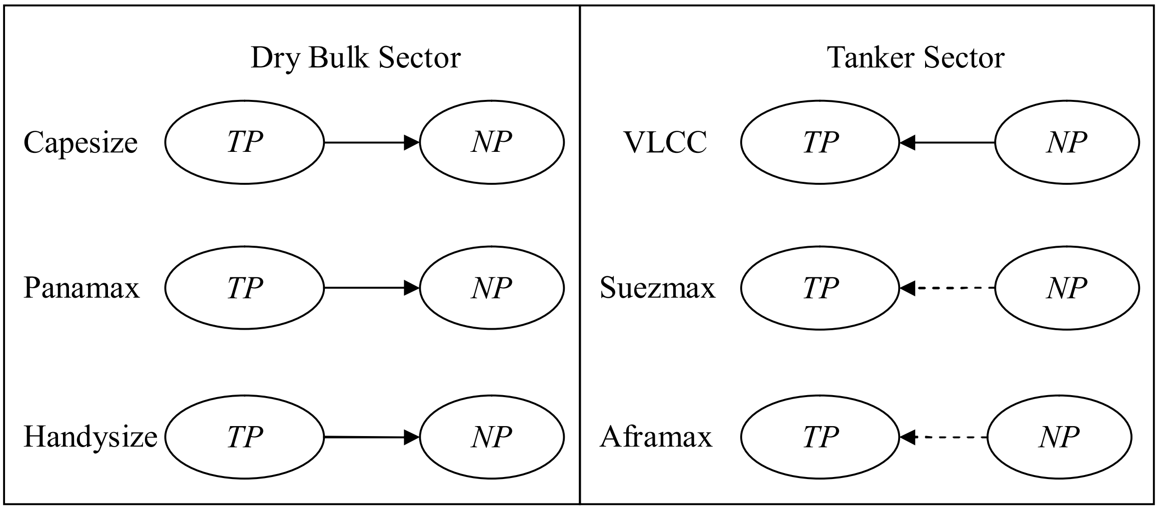
Suezmax ship segments. While for the other ship segments, the changes in fact enhance the conclusion that, in most cases, the second-hand ship price leads the new-building ship price in the dry bulk sector but the new-building ship price leads the second-hand ship price in the tanker sector.

Table 4-6: Granger Causality Test Results between *NP* and *TP*

Segments	Lags	Non-causality Hypothesis	χ^2 statistics	*p*-value
Capesize	q=1	*TP* does not Granger cause *NP*	$\chi^2(1)$= 10.02487	0.0015**
		NP does not Granger cause *TP*	$\chi^2(1)$= 3.533392	0.0601
Panamax	q=1	*TP* does not Granger cause *NP*	$\chi^2(1)$= 22.92313	0.0000**
		NP does not Granger cause *TP*	$\chi^2(1)$= 3.643721	0.0563
Handysize	q=1	*TP* does not Granger cause *NP*	$\chi^2(1)$= 22.69133	0.0000**
		NP does not Granger cause *TP*	$\chi^2(1)$= 1.675075	0.1956
VLCC	q=2	*TP* does not Granger cause *NP*	$\chi^2(2)$=3.946186	0.1390
		NP does not Granger cause *TP*	$\chi^2(2)$=14.68829	0.0006**
Suezmax	q=1	*TP* does not Granger cause *NP*	$\chi^2(1)$= 0.448948	0.5028
		NP does not Granger cause *TP*	$\chi^2(1)$= 4.161545	0.0414*
Aframax	q=1	*TP* does not Granger cause *NP*	$\chi^2(1)$= 3.562647	0.0591
		NP does not Granger cause *TP*	$\chi^2(1)$= 6.247086	0.0124*

Notes:
1. *NP* and *TP* are used to represent the new-building and 10-year-old second-hand ship prices respectively.
2. * indicates statistical significance at 5% level; ** indicates statistical significance at 1% level.

Figure 4-3: Lead-lag Relationships between *NP* and *TP*



Notes:
1. *NP* and *TP* are to represent the new-building and 10-year-old second-hand ship prices respectively.
2. The solid line indicates that Granger causality is significant at 1% level, while the dashed line indicates that Granger causality is significant at 5% level.
3. Lead-lag relationships are based on the results in Table 4-6.

4.4 Relationships between the new-building and 5-year-old ship prices for the sub-period (1998-2008)

Past studies on the ship prices covered a relatively outdated research sample mainly before 1998 (*Glen 1997, Alizadeh-Masoodian 2001, Kavussanos and Alizadeh 2002a*). It is possible that the behavior of ship prices and their relationship patterns may have changed after 1998. In addition, it has been discussed that the results within relatively recent periods seem to enhance the conclusion that the second-hand ship price leads new-building price in the dry bulk sector most of the time while the opposite is true in the tanker sector. Accordingly, a test using the more recent periods is then conduct to check whether this lead-lag relationship would change in the dry bulk sector along with the booming market condition, and whether the opposite results in the dry bulk and tanker sectors can be further confirmed.

A sub-period from Jan. 1998 to October 2008 is chosen. Jan. 1998 is chosen as the cut-off point because this sub-period should be long enough to cover more than one complete shipping cycle according to *Stopford* (*2009*).

Table 4-7 gives the results of the Johansen test of co-integration between *NP* and *FP* within this sub-period. Difference occurs in the Suezmax segment since cointegration exists within the whole period (from 1983 to 2008) but does not exist for this sub-period. For other ship segments, the existence of cointegration remains unchanged. Thus, no long-run relation exists for all the tanker segments in this booming period. This result again indicates the new-building and second-hand ship prices tie more closely in the dry bulk sector than in the tanker sector. From Figure 1, it can be observed that the second-hand ship prices even exceed the new-building prices occasionally for the dry bulk carriers after 2000. For the more recent sub-period, this phenomenon may be the key factor that affected the existence of co-integration. Since cointegration is not the main concern in this study, the Granger causality test is applied directly to check the results of the lead-lag relationship during this sub-period.

Table 4-7: Cointegration Test Results for the Sub-period (1998 - 2008)

Ship type	Lags	H_0	$\lambda_{\max}$	0.05 Critical Value	Prob.	λ_{trace}	0.05 Critical Value	Prob.
Capesize	q=2	r=0	19.8637	14.265	0.0059**	20.1645	15.495	0.0092**
		$r\leq 1$	0.30079	3.8415	0.5834	0.30079	3.8415	0.5834
Panamax	q=2	r=0	19.53795	14.265	0.0067**	19.80559	15.495	0.0105*
		$r\leq 1$	0.267640	3.8415	0.6049	0.267640	3.8415	0.6049
Handysize	q=2	r=0	14.15365	14.265	0.0520	14.17311	15.495	0.0783
		$r\leq 1$	0.019469	3.8415	0.8889	0.019469	3.8415	0.8889
VLCC	q=2	r=0	10.19310	14.265	0.1995	10.27275	15.495	0.2603
		$r\leq 1$	0.079646	3.8415	0.7778	0.079646	3.8415	0.7778
Suezmax	q=3	r=0	8.548000	14.265	0.3257	8.572628	15.495	0.4064
		$r\leq 1$	0.024628	3.8415	0.8752	0.024628	3.8415	0.8752
Aframax	q=2	r=0	6.191645	14.265	0.5887	6.191811	15.495	0.6729
		$r\leq 1$	0.000165	3.8415	0.9914	0.000165	3.8415	0.9914

Notes: * indicates statistical significance at 5% level; ** indicates statistical significance at 1% level.

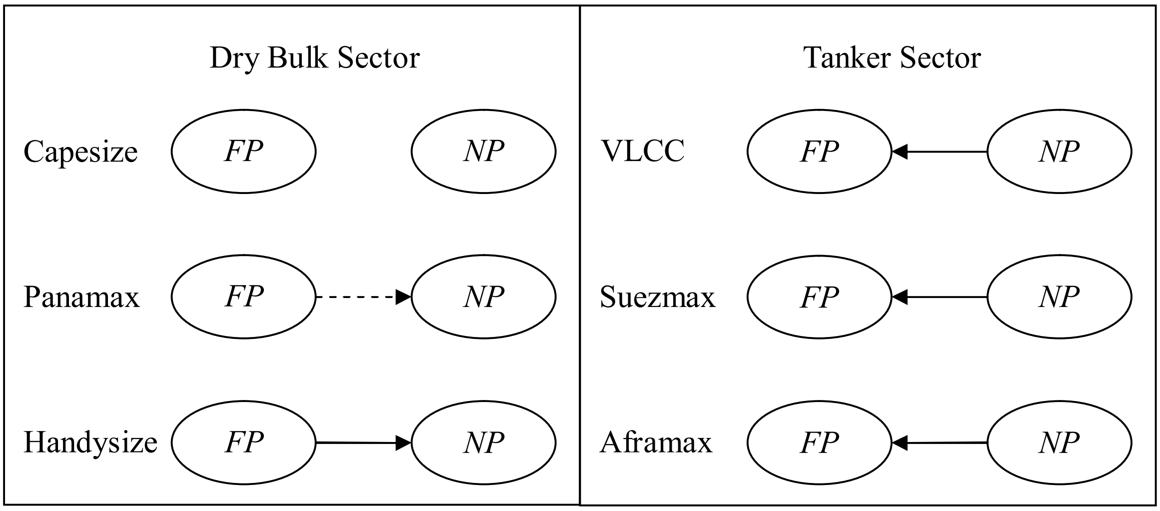
Table 4-8 and Figure 4-4 summarize the Granger causality test results for this sub-period. As shown in Figure 4-4, causality from *FP* to *NP* exists in the Panamax and Handysize ship segments of the dry bulk sector, while the lead-lag relationships are all from *NP* to *FP* in the tanker sector. Although the temporal relationships are not tight in the Capesize segment, the results from other ship segments are similar to the results drawn from *NP* and *TP,* namely *FP* leads *NP* in the dry bulk sector but opposite in the tanker sector. Clearly, time period has a great impact on the lead-lag relationships between new-building and second-hand ship prices. It implies that the lead-lag relationship between the new-building and second-hand ship prices is not always stable and could be affected by the time period examined. More specifically, this temporal relationship could in fact be influenced by the changes of the whole shipping environment. It could be concluded for this booming sub-period that the second-hand ship price leads the new-building price in the dry bulk sector whereas in the tanker sector, the opposite is true.

Table 4-8: Granger Causality Test Results for the Sub-period after 1998

Segments	Lags	Non-causality Hypothesis	χ^2 statistics	*p*-value
Capesize	q=1	*FP* does not Granger cause *NP*	$\chi^2(1)$=0.519961	0.4709
		NP does not Granger cause *FP*	$\chi^2(1)$=0.350941	0.5536
Panamax	q=1	*FP* does not Granger cause *NP*	$\chi^2(1)$= 6.334709	0.0118*
		NP does not Granger cause *FP*	$\chi^2(1)$= 2.961732	0.0853
Handysize	q=1	*FP* does not Granger cause *NP*	$\chi^2(1)$= 10.22832	0.0014**
		NP does not Granger cause *FP*	$\chi^2(1)$= 2.071659	0.1501
VLCC	q=1	*FP* does not Granger cause *NP*	$\chi^2(1)$= 0.365850	0.5453
		NP does not Granger cause *FP*	$\chi^2(1)$= 16.13112	0.0001**
Suezmax	q=2	*FP* does not Granger cause *NP*	$\chi^2(2)$= 2.109618	0.3483
		NP does not Granger cause *FP*	$\chi^2(2)$= 9.290149	0.0096**
Aframax	q=1	*FP* does not Granger cause *NP*	$\chi^2(1)$= 1.736710	0.1876
		NP does not Granger cause *FP*	$\chi^2(1)$= 9.910921	0.0016**

Notes:
1. *NP* and *FP* are used to represent the new-building and 5-year-old second-hand ship prices respectively.
2. * indicates statistical significance at 5% level; ** indicates statistical significance at 1% level.

Figure 4-4: Lead-lag Relationships between *NP* and *FP* in the Sub-period (1998~2008)



Notes:
1. *NP* and *FP* are used to represent the new-building and 5-year-old second-hand ship prices respectively.
2. The solid line indicates that Granger causality is significant at 1% level, while the dashed line indicates that Granger causality is significant at 5% level.
3. Lead-lag relationships are based on the results in Table 4-8.

4.5 Relationships between the average ship prices in the dry bulk and tanker sectors

It has been found that the lead-lag relationships are not exactly the same in each ship segment within one sector, and different ship types have their specific properties. This raises a question on what are the lead-lag relationships for the two shipping sectors as a whole individually. In this sub-section, another test with the average new-building and 5-year-old second-hand ship prices is conducted to examine whether the conclusions for individual shipping segments remain true or not.

BNP and *BFP* are used to denote the average new-building and 5-year-old second-hand prices, respectively, in the dry bulk sector. Similarly, *TNP* and *TFP* denote the same variables in the tanker sector. The whole data sample is from Jan. 1976 to Oct. 2008. The time line is also chosen from Jan. 1998 to Oct. 2008 as the sub-period to examine whether the opposite lead-lag relationship for the dry bulk and tanker sectors are stronger than it from the whole data sample.

Table 4-9 gives the results of the co-integration test with the Johansen method for both the whole (Panel A) and the sub (Panel B) periods. The results from these two panels suggest that the *BNP* and *BFP* are not co-integrated for the whole period but they are co-integrated for the sub-period in the dry bulk sector. The findings are basically in line with the analysis in specific ship segment because the results from either λ_{trace} or λ_{max} statistics indicate that, for the Capesize and Panamax ship segments, the existences of co-integration between *NP* and *FP* are more significant in the sub-period than those in the whole sample period. For the results from tanker sector, the findings are also in line with the results from specific ship types, i.e. no co-integration exists between two ship prices in this shipping sector.

Table 4-9: Cointegration Test Results between the Average New-building and 5-year-old Ship Prices

Panel A: Johansen test (Jan. 1976 ~ Oct. 2008)								
Sector	Lags	H_0	$\lambda_{\max}$	0.05 Critical Value	Prob.	λ_{trace}	0.05 Critical Value	Prob.
Dry bulk	q=3	r=0	6.828452	14.265	0.5096	7.818540	15.495	0.4850
		$r\leq 1$	0.990088	3.8415	0.3197	0.990088	3.8415	0.3197
Tanker	q=3	r=0	6.829351	14.265	0.5095	8.422622	15.495	0.4214
		$r\leq 1$	1.593270	3.8415	0.2069	1.593270	3.8415	0.2069
Panel B: Johansen test (Jan. 1998 ~ Oct. 2008)								
Sector	Lags	H_0	$\lambda_{\max}$	0.05 Critical Value	Prob.	λ_{trace}	0.05 Critical Value	Prob.
Dry bulk	q=2	r=0	17.99884	14.265	0.0123*	18.04606	15.495	0.0202*
		$r\leq 1$	0.047221	3.8415	0.8279	0.047221	3.8415	0.8279
Tanker	q=2	r=0	9.549911	14.265	0.2432	10.17034	15.495	0.2679
		$r\leq 1$	0.620425	3.8415	0.4309	0.620425	3.8415	0.4309

Notes: * denotes rejection the hypothesis of no cointegrating equation at 5% level; ** denotes rejection the hypothesis of no cointegrating equation.

Table 4-10 below reveal the Granger causalities between the average new-building and 5-year-old second-hand ship prices in the dry bulk and tanker sectors. As shown in Panel A of Table 4-10, *TNP* significantly leads *TFP*. From Panel B in Table 4-10, it can be observed that the causality from *TNP* to *TFP* is much stronger than it is from *TFP* to *TNP*. The results from average data series are in line with our general conclusions for single ship segments in most cases, i.e., the second-hand ship price leads the new-building price in the dry bulk sector while the opposite is true in the tanker sector. Consequently, the new-building and second-hand ship prices do not react to the new information simultaneously, instead there exists a temporal response difference. Specifically, the second-hand ship price leads the new-building ship price by 2 to 3 months in the dry bulk sector while the opposite lead-lag relation between two prices in the tanker sector.

Table 4-10: Granger causality Test Results between the Average New-building and 5-year-old Ship Prices

Panel A: Granger causality test (Jan. 1976 ~ Oct. 2008)				
Sector	Lags	Non-causality Hypothesis	χ^2 statistics	p-value
Dry bulk	q=2	*BFP* does not Granger cause *BNP*	$\chi^2(2)$= 20.80490	0.0000**
		BNP does not Granger cause *BFP*	$\chi^2(2)$= 5.509353	0.0636
Tanker	q=2	*TFP* does not Granger cause *TNP*	$\chi^2(2)$= 4.401381	0.1107
		TNP does not Granger cause *TFP*	$\chi^2(2)$= 10.97998	0.0041**
Panel B: Granger causality test (Jan. 1998 ~ Oct. 2008)				
Sector	Lags	Non-causality Hypothesis	χ^2 statistics	p-value
Dry bulk	q=1	*BFP* does not Granger cause *BNP*	$\chi^2(1)$= 23.61928	0.0000**
		BNP does not Granger cause *BFP*	$\chi^2(1)$= 0.380321	0.5374
Tanker	q=1	*TFP* does not Granger cause *TNP*	$\chi^2(1)$= 4.671697	0.0307*
		TNP does not Granger cause *TFP*	$\chi^2(1)$= 18.44101	0.0000**

Notes:
1. *BNP* and *BFP* are used to represent the average new-building and 5-year-old second-hand ship prices in the dry bulk sector, respectively. *TNP* and *TFP* are the same variables in the tanker sector.
2. * indicates statistical significance at 5% level; ** indicates statistical significance at 1% level.

So far, this section focused on the lead-lag relationship between the new-building and second-hand ship prices. The tests based on econometric techniques reveal a result contradictory to the past views in the tanker sector. Since previous studies have indicated that the economic structures in the dry bulk and tanker sectors are sufficiently different (*Veenstra 1999, Haralambides et al. 2004*), then it is possible to draw different results from these two sectors. The question is why the lead-lag relations in two shipping sectors are different.

It is noticed that *BFP* leads *BNP* (*BFP→BNP*) and *TNP* leads *TFP* (*TNP→TFP*) from the average test results. Then if *BNP→TNP*, i.e., if the new-building price in the dry bulk sector leads the new-building price in the tanker sector, there may have one explanation for this opposite relationship by if the average new-building tanker price follows the pattern of the average new-building dry bulk price. To see if this is the case, it is assumed that there exists a lead-lag relationship between the average new-building dry bulk and tanker prices, and the price in the dry bulk sector leads the one in the tanker sector, namely *BNP→TNP.* The test results on the lead-lag relationship between *BNP* and *TNP* in Table 4-11 verify the assumption that the new-building ship price in the dry bulk sector responds to the new information faster than it in the tanker sector.

Table 4-11: Cointegration and Granger Causality Test Results between *BNP* and *TNP*

Panel A: Johansen test							
Lags	H_0	$\lambda_{\max}$	0.05 Critical Value	Prob.	λ_{trace}	0.05 Critical Value	Prob.
q=3	r=0	12.38614	14.265	0.0970	13.78332	15.495	0.0891
	$r \leq 1$	1.397175	3.8415	0.2372	1.397175	3.8415	0.2372

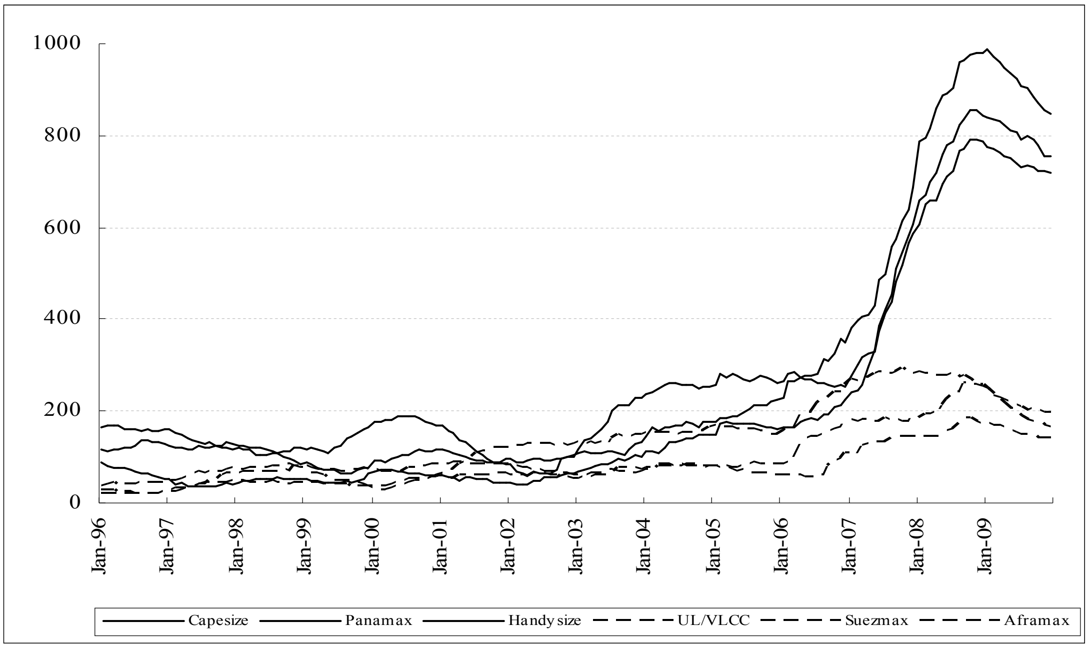
Panel B: Granger Causality Tests Based on VAR			
Lags	Non-causality Hypothesis	χ^2 statistics	p-value
q=1	*TNP* does not Granger cause *BNP*	$\chi^2(1)$= 4.942524	0.0845
q=1	*BNP* does not Granger cause *TNP*	$\chi^2(1)$= 11.21174	0.0037**

Notes:

1. *BNP* and *TNP* are used to represent the average new-building ship prices in the dry bulk and tanker sectors, respectively.
2. ** indicates statistical significance at 1% level.

The order books for all ship types in the dry bulk and tanker sectors are examined to see why the new-building dry bulk price leads the new-building tanker price. In Figure 4-5, the solid lines represent the order books for different dry bulk ship segments while the dashed lines represent the order books in the tanker sector. The sample period is from Jan. 1996 to Oct. 2008. It can be clearly seen that the ordering activities are more frequently in the dry bulk sector than in the tanker sector especially in the more recent periods. It has been discussed that the sub-period results strengthen our conclusion that the second-hand price leads the new-building price in dry bulk sector and the new-building leads the second-hand price in tanker sector. Therefore, the ordering activities may be a reason why the average new-building price in the dry bulk sector plays the role of a leader. Further analysis along this direction is beyond the scope of this.

Figure 4-5: Numbers of Order-books in All Ship Segments



Notes: The solid line represents order-books for the ship types concerned in the dry bulk sector while the dashed line stands for the order-books in the tanker sector.

Data source: Clarkson Research Services Limited 2010

Chapter 5: Relationships between the Freight and Ship Markets

5.1 Data analysis

The data used in this Chapter consist of the time series of monthly new-building, 5-year-old, 10-year-old second-hand ship prices, 6-month, 1-year and 3-year time charter rates for three different-size carriers in both dry bulk and tanker sectors from Clarkson Research Services Limited 2010, Lloyd's Shipping Economist and Fearnleys[12].

The categories of the ship segments and the data samples for ship prices in each sector are the same as in the Chapter 4. The notations of *NP*, *FP* and *TP* are still used to denote the new-building, 5-year-old and 10-year-old second-hand ship prices. For the time charter rates, *TC*6, *TC*1 and *TC*3 denote the 6-month, 1-year and 3-year time charter rates, respectively, and *TC* broadly means the time charter rate. The logarithmic transformation of series is also applied with all the data series. All ship prices are quoted in million dollars in each category while time charter rates are measured in dollars per day.

[12] Since the complete data set required for our analysis is not available from a single source, data are from different sources.

Two data problems should be noticed for the tanker sector. First, in the tanker shipping, ships are usually hired for a longer time period than they are in the dry bulk sector. Then *TC*6 is not available. Second, the original starting points of *TC*3 for all kinds of the tankers are from Dec. 2001 (Clarkson Research Services Limited 2010). Since the data series of *TC*1 are all from Jan. 2000, augmentations of *TC*3 from Jan. 2000 to Nov. 2001 (data are from Lloyd's Shipping Economist and Fearnleys) are made to enlarge these data samples. The data series after the adjustment are denoted as *TC*3'. It should be noticed that this augmentation may cause the *TC*3' series has a different deadweight occasionally. For example, the original *TC*3 from Dec. 2001 to Oct. 2008 are for 300,000 DWT VLCC vessels, while the data added from Jan. 2000 to Nov. 2001 are for 280,000 DWT VLCC vessels. Nevertheless, the deadweight's differentiation is relatively small. So the test results from *TC*3' are more trustable comparing with limited observations of *TC*3.

The starting points of time charter rate in the dry bulk sector are different for the separate ship segment. Table 5-1 summarized the descriptive statistics of these time charter rates. The results show that the means of time charter rate in tanker sector are higher than those in the dry bulk sector. The distributions of time charter rates in these two sectors are also different. Clearly, the skewness statistics in the tanker sector are all negative. It indicates that the time charter rates in the tanker sector are all skewed to the left but they are skewed to the right in the dry bulk sector (except *TC*6 in Panamax ship segment). The distributions of time charter rate series show the first impression of different structures of the dry bulk and tanker sectors.

Table 5-1: Descriptive Statistics of Time Charter Rates

Ship Segments	Variables	Start Point	Mean	*S.D.*	*Skew.*	*Kurt.*
Capesize	*TC*6	1992M01	9.972952	0.779519	0.902945	2.840678
	*TC*1	1991M12	9.969344	0.712581	1.053030	3.145595
	*TC*3	1991M12	9.922582	0.542329	1.365416	4.186691
Panamax	*TC*6	2001M03	10.09269	0.749481	-0.049278	1.937579
	*TC*1	1997M01	9.712629	0.724235	0.693374	2.258042
	*TC*3	1997M01	9.534579	0.626179	0.901381	2.775818
Handysize	*TC*6	1989M01	9.139389	0.539979	1.348711	3.902118
	*TC*1	1976M01	8.873130	0.548231	0.993875	4.202620
	*TC*3	1977M01	8.912694	0.424619	0.766831	4.421113
VLCC	*TC*1	2000M01	10.75119	0.346980	-0.382194	2.384623
	*TC*3’	2000M01	10.59804	0.260029	-0.109527	2.000271
	*TC*3	2001M12	10.62444	0.274956	-0.263743	1.913665
Suezmax	*TC*1	2000M01	10.46623	0.312957	-0.735650	2.557338
	*TC*3’	2000M01	10.32639	0.254372	-0.473845	1.884402
	*TC*3	2001M12	10.34754	0.270641	-0.630832	1.905431
Aframax	*TC*1	2000M01	10.21467	0.271129	-0.381605	1.893581
	*TC*3’	2000M01	10.07492	0.220498	-0.221163	1.641472
	*TC*3	2001M12	10.11290	0.225121	-0.501748	1.645162

Notes:
1. *TC*6, *TC*1, *TC*3 *and TC*3’ represent 6-month, 1-year, 3-year and augmented 3-year time charter rates, respectively.
2. *S. D.* means the standard deviation of a data set. *Skew.* and *Kurt.* are skewness and kurtosis statistics.

As discussed in Chapter 4, the next step is to examine the stationarity of time charter rates by ADF and PP tests. The results are summarized in Table 5-2. They suggest that all the time charter rates satisfy $I(1)$ process as ship price series.

Table 5-2: ADF and PP Test Results of Time Charter Rates

Levels					
Ship type	Variables	ADF	Type	PP	Critical value (5%)
Capesize	*TC*6	-2.423337	(C,0,1)	-1.900226	-2.875825
	*TC*1	-2.344354	(C,0,1)	-1.861235	-2.875752
	*TC*3	-2.781134	(C,0,1)	-1.896193	-2.875752
Panamax	*TC*6	-1.903429	(C,0,1)	-1.561945	-2.893956
	*TC*1	-2.224404	(C,0,1)	-1.435132	-2.882127
	*TC*3	-3.152113	(C,T,1)	-2.425200	-3.442238
Handysize	*TC*6	-2.477493	(C,0,1)	-1.711941	-2.873596
	*TC*1	-2.873950	(C,0,1)	-1.944988	-2.868694
	*TC*3	-3.258594	(C,T,2)	-2.852821	-3.421725
VLCC	*TC*1	-1.278331	(C,0,0)	-1.473504	-2.889753
	*TC*3’	-1.621794	(C,0,1)	-1.531560	-2.889474
	*TC*3	-1.220888	(C,0,1)	-0.874209	-2.897678
Suezmax	*TC*1	-1.863579	(C,0,1)	-1.535031	-2.890037
	*TC*3’	-1.168168	(C,0,1)	-1.413216	-2.889474
	*TC*3	-1.385576	(C,0,2)	-0.984879	-2.898145
Aframax	*TC*1	-1.882442	(C,0,1)	-1.174343	-2.890037
	*TC*3’	-1.406858	(C,0,1)	-1.893023	-2.889474
	*TC*3	-0.908958	(C,0,2)	-0.922730	-2.898145
First Differences					
Capesize	Δ*TC*6	-6.522075	(C,0,0)	-6.422120	-2.875825**
	Δ*TC*1	-5.749310	(C,0,0)	-5.749310	-2.875752**
	Δ*TC*3	-4.071120	(C,0,0)	-4.339225	-2.875752**
Panamax	Δ*TC*6	-3.510336	(C,0,0)	-3.639755	-2.893956**
	Δ*TC*1	-3.826829	(C,0,0)	-3.689187	-2.882127**
	Δ*TC*3	-3.953446	(C,0,0)	-3.958293	-2.882127**
Handysize	ΔTC6	-5.453325	(C,0,0)	-5.611036	-2.873596**
	ΔTC1	-8.090486	(C,0,0)	-8.241175	-2.868694**
	ΔTC3	-7.799785	(C,0,1)	-15.05571	-2.868948**

Table 5-2: ADF and PP Test Results of Time Charter Rates (Continued)

VLCC	$\Delta TC1$	-8.280716	(C,0,0)	-8.126538	-2.890037**
	$\Delta TC3'$	-6.673287	(C,0,0)	-6.566736	-2.889474**
	$\Delta TC3$	-6.582539	(C,0,0)	-6.550265	-2.897678**
Suezmax	$\Delta TC1$	-6.647086	(C,0,0)	-6.582376	-2.890037**
	$\Delta TC3'$	-7.354539	(C,0,0)	-7.402879	-2.889474**
	$\Delta TC3$	-6.893900	(C,0,1)	-6.278835	-2.898145**
Aframax	$\Delta TC1$	-6.445675	(C,0,0)	-6.092358	-2.890037**
	$\Delta TC3'$	-7.743284	(C,0,0)	-7.596272	-2.889474**
	$\Delta TC3$	-6.952129	(C,0,1)	-5.632809	-2.898145**

Notes:

1. *TC*6, *TC*1, *TC*3 *and TC*3' represent 6-month, 1-year, 3-year and augmented 3-year time charter rates, respectively.
2. Δ stands for the first difference value.
3. (C, T,*) represents (constant, trend, lagged order)
4. Critical values are based on ADF test;
5. ** denotes the statistical significance is at 1% level.

5.2 Relationships between the average freight rate and ship prices

Firstly, this chapter considers the temporal relationship between the freight and ship markets at a sector level. In other words, different ship segments are not specified in this sub-section. Instead, the average ship prices (*NP* and *FP*) and freight rate will be concerned.

For the freight rates, Baltic Dry Index (*BDI*) and Baltic Dirty Tanker Index (*BDTI*) are collected. *B* and *T* used as initial letters to represent the dry bulk and tanker sectors, respectively. Table 5-3 gives the test results of cointegration. It shows that one long-run relationship exists between freight rate, new-building and second-hand ship prices in both of the two shipping sectors. It has been found in Chapter 4 that there is no cointegration between the average new-building and second-hand ship prices. The change of the existence of cointegration implies that the freight rate is the variable that ties the new-building and second-hand ship prices together in the long run.

Table 5-3: Cointegration Test Results in Two Shipping Sectors

Variables	Lags	Hypothesized No. of CE(s)	$\lambda_{\max}$	0.05 Critical Value	λ_{trace}	0.05 Critical Value
			Dry bulk sector			
BDI, *BNP* and *BFP*	q=2	None	42.28247**	21.13162	52.78466**	29.79707
		At most 1	7.678534	14.26460	10.50219	15.49471
		At most 2	2.823656	3.841466	2.823656	3.841466
			Tanker sector			
BDTI, *TNP* and *TFP*	q=2	None	28.27488**	21.13162	38.91243**	29.79707
		At most 1	9.790031	14.26460	10.63755	15.49471
		At most 2	0.847516	3.841466	0.847516	3.841466

Notes:
1. *BDI* and *BDTI* are Baltic Dry Index and Baltic Dirty Tanker Index respectively. *BNP* and *BFP* represent the average new-building and 5-year-old second-hand ship prices in the dry bulk sector, while *TNP* and *TFP* are the same variables in the tanker sector.
2. ** indicates statistical significance at 1% level.

Table 5-4 summarized the results from Granger causality test based on VEC model. The temporal relations among these three variables are shown in Figure 5-1. As they shown, the temporal linkages between the freight rate and ship prices are different for the dry bulk and tanker sectors. For the dry bulk sector, *BDI* significantly leads *BNP* or *BFP*. This result is in line with the practical fact that *BDI* is usually viewed as a leading economic indicator of the whole shipping industry. However, in the tanker sector, *BDTI* is more independent than *BDI* since *BDTI* has no causal links to any of the ship prices. Another notable difference in two shipping sectors has discussed in last Chapter, i.e. the temporal relationships between average new-building and second-hand ship prices are opposite in this two shipping sectors. Results drawn from three-dimension system further confirmed this conclusion.

Despite the different relationships among three variables, similarities also exist. As shown in Table 5-4, in both two shipping sectors, the system of the freight rate and new-building ship price leads the second-hand ship price. Then the second-hand ship price plays the same role in two shipping sectors from the view of temporal relationships. This conclusion is contrary to the inference by *Veenstra (1999)* who suggested the different structures in two shipping sectors may cause by the second-hand ship price. Consequently, further tests with specific ship segments should be conducted to find out the other possible reasons behind this phenomenon.

Table 5-4: Granger Causality Test Results in Two Shipping Sectors

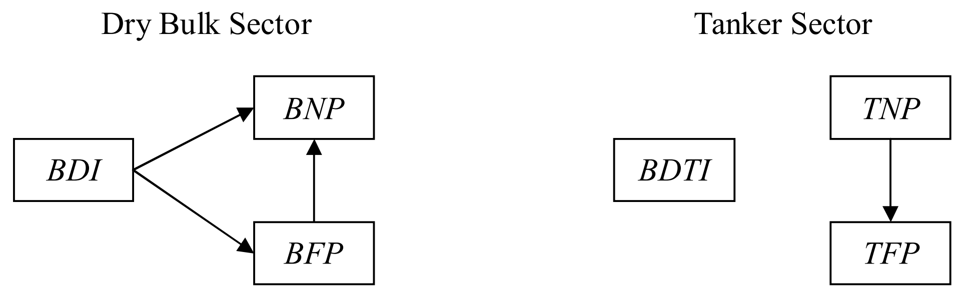
Dry bulk sector			Tanker sector		
Effect variable:	Cause Variables	χ^2 Statistics (p-value)	Effect variable:	Cause Variables	χ^2 Statistics and p-value
$\triangle BNP$	$\triangle BFP$	9.554125 (0.0020**)	$\triangle TNP$	$\triangle TFP$	0.766518 (0.3813)
	$\triangle BDI$	3.402933 (0.0043**)		$\triangle BDTI$	0.210741 (0.6462)
	$\triangle BFP$&$\triangle BDI$	21.71577 (0.0000**)		$\triangle TFP$&$\triangle BDTI$	0.859824 (0.6506)
$\triangle BFP$	$\triangle BNP$	1.468525 (0.2256)	$\triangle TFP$	$\triangle TNP$	11.01345 (0.0009**)
	$\triangle BDI$	12.66084 (0.0004**)		$\triangle BDTI$	1.269546 (0.2599)
	$\triangle BNP$&$\triangle BDI$	16.50291 (0.0003**)		$\triangle TNP$&$\triangle BDTI$	11.88851 (0.0026**)
$\triangle BDI$	$\triangle BNP$	0.169930 (0.6802)	$\triangle BDTI$	$\triangle TNP$	1.253825 (0.2628)
	$\triangle BFP$	0.291508 (0.5893)		$\triangle TFP$	0.005920 (0.9387)
	$\triangle BNP$&$\triangle BFP$	0.322803 (0.8510)		$\triangle TNP$&$\triangle TFP$	1.298268 (0.5225)

Notes:

1. *BDI* and *BDTI* are Baltic Dry Index and Baltic Dirty Tanker Index respectively. *BNP* and *BFP* represent the average new-building and 5-year-old second-hand ship prices in the dry bulk sector, while *TNP* and *TFP* are the same variables in the tanker sector.
2. * indicates statistical significance at 5% level; ** indicates significance at 1% level.

The analysis of the temporal relationships above is from the sector level. The limitation of using *BDTI* is that this index measured on a time charter and voyage basis. However, very few tankers are operated in the spot market. Instead, majority independent tankers are on a long-term charter. *Hawdon (1978)* has pointed out that the concentration in the spot market is very low in tanker shipping. *Haralambides* *et al. (2005)* have also indicated the voyage rates are seldom a driver to the new-building ordering. Previous studies demonstrated that it is better to choose the time charter rate to represent the freight market. Next step, the tests using time charter rates with specific ship types are carried out to analyze the temporal linkages among the freight and ship markets.

Figure 5-1: Relationships among Three Markets in Two Shipping Sectors with Average Data Series



Notes:

1. *BDI* and *BDTI* are Baltic Dry Index and Baltic Dirty Tanker Index respectively. *BNP* and *BFP* represent the average new-building and 5-year-old second-hand ship prices in the dry bulk sector, while *TNP* and *TFP* are the same variables in the tanker sector.
2. The solid line indicates the lead-lag relationship is significant at 1% level.
3. Lead-lag relationships are based on the results in Table 5-4.

5.3 Relationships between the freight and ship markets in the dry bulk sector

In this sub-section, two kinds of second-hand ship prices (5-year-old and 10-year-old) and three different durations of time charters (6-month, 1-year and

3-year time charter rates) are examined. The analysis of temporal relationships under three-variable framework is more complex than the two-variable framework. First, it needs to investigate the lead-lag relationship between every pair of the three variables, i.e. relationships between *NP*&*FP*, *NP*&*TC*, and *FP*&*TC*. Second, for the three-dimensional framework, the leading indicator should be examined by testing the relationships between one variable and the system of the other two variables, i.e. relationships between (*NP*, *FP*)&*TC*, (*NP*, *TC*)&*FP*, and (*FP*, *TC*)&*NP*.

As discussed above, to study this issue, the existence of cointegration among the variables should be first determined. *Johansen (1988)* technique is applied as a primary tool. For the test in this chapter involving three variables, Engle-Granger two-step method is not available. Instead, the test proposed by *Saikkonen and Lütkepohl (2000a, b, c)* (S&L test) is applied to double check the existence of cointegration when λ_{trace} and λ_{max} statistics suggest contradictory results.

The relationships among *NP*, *FP* and *TC* in the dry bulk sector are examined first. The cointegration test results are summarized in Table 5-5. As the findings shown in Panel A, *NP*, *FP* and *TC* are significantly cointegrated for the Capesize and Handysize ship segments. For the Panamax vessels, cointegration does not exist with λ_{max} statistic for all the three time charters but exist with λ_{trace} statistic for *TC*1 and

*TC*3. Since the inconsistent results for 1-year and 3-year time charters in the Panamax ship segment, S&L test using JMulTi software is then conducted to re-examine the existence of cointegration. The test results are summarized in Panel B in Table 5-5. As it shown, the results from this method are the same as λ_{max} statistic, i.e. no cointegration exists for the Panamax ship segment for all the time charters. It is noticed from Chapter 4 that *NP* and *FP* are cointegrated for the Panamax vessels either with Johansen or Engle-Granger two-step method. It indicates that the new-building and second-hand ship prices bound more closely in the Panamax ship segments than the other segments in the dry bulk sector.

Table 5-5: Cointegration Test Results among *NP*, *FP* and *TC* in the Dry Bulk Sector

Panel A: Johansen test						
Variables	Lags	Hypothesized No. of CE(s)	$\lambda_{\max}$	0.05 Critical Value	λ_{trace}	0.05 Critical Value
Capesize						
*TC*6, *NP* and *FP*	q=2	None	38.35515**	21.1316	56.41309**	29.7971
		At most 1	15.33313*	14.2646	18.05794*	15.4947
		At most 2	2.724816	3.84147	2.724816	3.84147
*TC*1, *NP* and *FP*	q=2	None	33.36389**	21.1316	52.52243**	29.7971
		At most 1	15.90989*	14.2646	19.15854*	15.4947
		At most 2	3.248650	3.84147	3.248650	3.84147
*TC*3, *NP* and *FP*	q=2	None	29.78122**	21.1316	43.12533**	29.7971
		At most 1	12.89426	14.2646	13.34411	15.4947
		At most 2	0.449850	3.84147	0.449850	3.84147

Table 5-5: Cointegration Test Results among *NP*, *FP* and *TC* in the Dry Bulk Sector

(Continued)

Panamax						
*TC*6, *NP* and *FP*	*q*=2	None	15.39198	21.1316	21.43779	29.7971
		At most 1	3.531453	14.2646	6.045812	15.4947
		At most 2	2.514359	3.84147	2.514359	3.84147
*TC*1, *NP* and *FP*	*q*=2	None	19.99872	21.1316	31.72669*	29.7971
		At most 1	9.758807	14.2646	11.72797	15.4947
		At most 2	1.969166	3.84147	1.969166	3.84147
*TC*3, *NP* and *FP*	*q*=2	None	20.82361	21.1316	35.43023*	29.7971
		At most 1	14.13173	14.2646	14.60661	15.4947
		At most 2	0.474882	3.84147	0.474882	3.84147
Handysize						
*TC*6, *NP* and *FP*	*q*=2	None	32.39823**	21.1316	43.73723**	29.7971
		At most 1	8.336806	14.2646	11.33900	15.4947
		At most 2	3.002197	3.84147	3.002197	3.84147
*TC*1, *NP* and *FP*	*q*=2	None	39.88722**	21.1316	56.05595**	29.7971
		At most 1	12.94879	14.2646	16.16873*	15.4947
		At most 2	3.219941	3.84147	3.219941	3.84147
*TC*3, *NP* and *FP*	*q*=2	None	21.98259*	21.1316	36.05628**	29.7971
		At most 1	11.75978	14.2646	14.07369	15.4947
		At most 2	2.313907	3.84147	2.313907	3.84147

Panel B: S&L test

Variables	Lags	Hypothesized No. of CE(s)	LR Statistics	0.05 Critical Value	*p* Value
Panamax					
*TC*1, *NP* and *FP*	*q*=2	None	21.63	24.16	0.1035
		At most 1	3.34	12.26	0.7994
		At most 2	1.38	4.13	0.2789
*TC*3, *NP* and *FP*	*q*=2	None	16.79	24.16	0.3307
		At most 1	10.10	12.26	0.1149
		At most 2	0.59	4.13	0.4999

Notes:

1. *NP* and *FP* represent the new-building and 5-year-old second-hand ship prices. *TC*6, *TC*1 *and TC*3 represent 6-month, 1-year and 3-year time charter rates, respectively.
2. * indicates statistical significance at 5% level; ** indicates significant at 1% level.

After determining the existence of cointegration, the temporal relationships between every pair of *NP*, *FP* and *TC* are examined first. Granger causality test in Eviews 6.0 gives χ^2 statistics of this kind of relations. From cointegraion results in Table 5-5, VEC model with one cointegration[13] is applied to the Capesize and Handysize ship segments, while VAR model with first difference data series is applied to the Panamax ship segment.

Table 5-6: Granger Causality Test Results among *NP*, *FP* and *TC* in the Dry Bulk Sector

Dependent variable	χ^2 Statistics (p-value)	Dependent variable	χ^2 Statistics (p-value)	Dependent variable	χ^2 Statistics (p-value)
Capesize VEC(1) - *NP*, *FP*, *TC*6					
△*NP*	△*FP* 0.0225(0.8807) △*TC*6 8.1387(0.0043**)	△*FP*	△*NP* 0.0041(0.9491) △*TC*6 18.321(0.0000**)	△*TC*6	△*NP* 4.6630(0.0308*) △*FP* 0.2437(0.6215)
Capesize VEC(1) - *NP*, *FP*, *TC*1					
△*NP*	△*FP* 0.4633(0.4961) △*TC*1 15.524(0.0001**)	△*FP*	△*NP* 0.1874(0.6651) △*TC*1 32.094(0.0000**)	△*TC*1	△*NP* 3.3360(0.0678) △*FP* 0.9753(0.3234)
Capesize VEC(1) - *NP*, *FP*, *TC*3					
△*NP*	△*FP* 0.0861(0.7691) △*TC*3 8.1763(0.0042**)	△*FP*	△*NP* 0.1742(0.6764) △*TC*3 46.782(0.0000**)	△*TC*3	△*NP* 0.6894(0.4064) △*FP* 0.1607(0.6886)
Panamax VAR(1) - *NP*, *FP*, *TC*6					
△*NP*	△*FP* 0.0171(0.8961) △*TC*6 17.152(0.0000**)	△*FP*	△*NP* 3.3088(0.0689) △*TC*6 18.104(0.0000**)	△*TC*6	△*NP* 0.0154(0.9012) △*FP* 1.3541(0.2446)

[13] Only one cointegration can be found in JMulTi software either with Johansen or S&L test method.

Table 5-6: Granger Causality Test Results among *NP*, *FP* and *TC* in the Dry Bulk Sector (Continued)

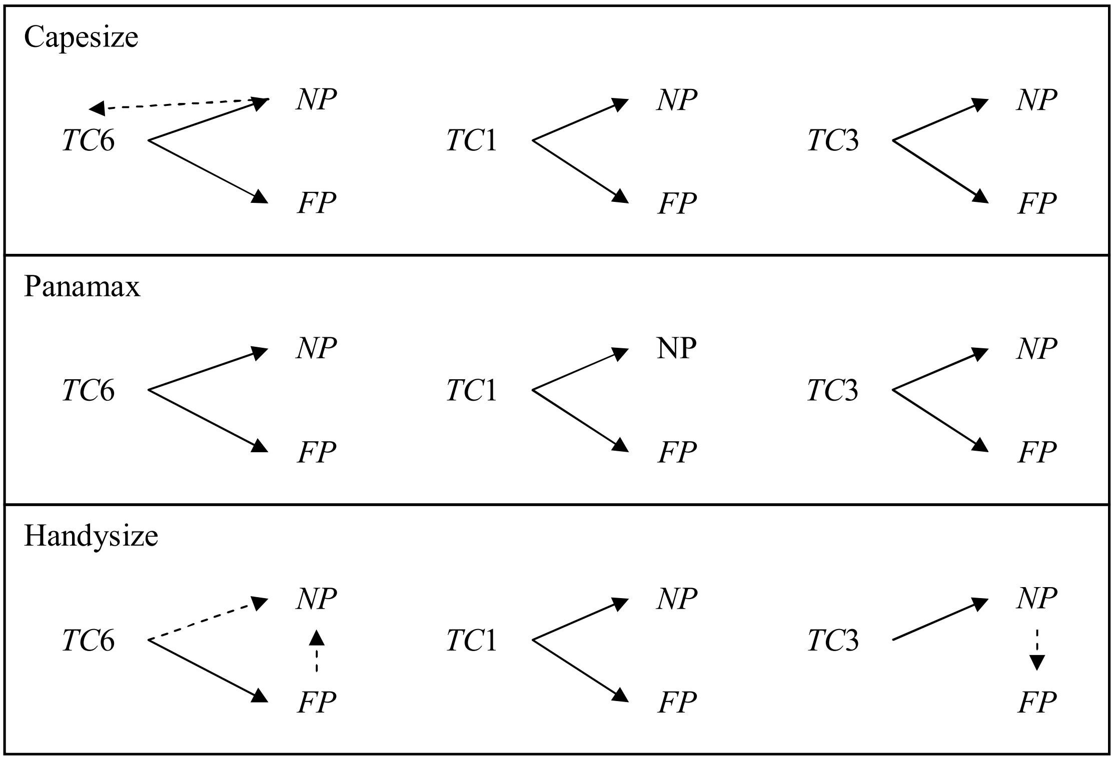
Panamax VAR(1) - NP, FP, TC1					
$\triangle NP$	$\triangle FP$	$\triangle FP$	$\triangle NP$	$\triangle TC1$	$\triangle NP$
	0.1976(0.6567)		1.6501(0.1989)		1.7369(0.1875)
	$\triangle TC1$		$\triangle TC1$		$\triangle FP$
	29.950(0.0000**)		32.090(0.0000**)		2.2180(0.1364)
Panamax VAR(1) - *NP*, *FP*, *TC*3					
$\triangle NP$	$\triangle FP$	$\triangle FP$	$\triangle NP$	$\triangle TC3$	$\triangle NP$
	1.5822(0.2084)		2.1314(0.1443)		0.0404(0.8407)
	$\triangle TC3$		$\triangle TC3$		$\triangle FP$
	34.369(0.0000**)		27.941(0.0000**)		0.0002(0.9889)
Handysize VEC(1) - *NP*, *FP*, *TC*6					
$\triangle NP$	$\triangle FP$	$\triangle FP$	$\triangle NP$	$\triangle TC6$	$\triangle NP$
	6.5618(0.0104*)		0.1000(0.7518)		1.8920(0.1690)
	$\triangle TC6$		$\triangle TC6$		$\triangle FP$
	4.9341(0.0263*)		9.5778(0.0020**)		2.9718(0.0847)
Handysize VEC(1) - *NP*, *FP*, *TC*1					
$\triangle NP$	$\triangle FP$	$\triangle FP$	$\triangle NP$	$\triangle TC1$	$\triangle NP$
	1.9441(0.1632)		1.2423(0.2650)		0.7398(0.3897)
	$\triangle TC1$		$\triangle TC1$		$\triangle FP$
	8.6548(0.0033**)		19.940(0.0000**)		2.8616(0.0907)
Handysize VEC(2) - *NP*, *FP*, *TC*3					
$\triangle NP$	$\triangle FP$	$\triangle FP$	$\triangle NP$	$\triangle TC3$	$\triangle NP$
	4.3889(0.1114)		8.6856 (0.0130*)		3.7756(0.1514)
	$\triangle TC3$		$\triangle TC3$		$\triangle FP$
	9.7962(0.0075**)		4.6970(0.0955)		5.0112(0.0816)

Notes:

1. *NP* and *FP* represent the new-building and 5-year-old second-hand ship prices. *TC*6, *TC*1 *and TC*3 represent 6-month, 1-year and 3-year time charter rates, respectively.
2. * indicates statistical significance at 5% level; ** indicates significant at 1% level.

The test results are presented in Table 5-6, and the directions of temporal relationships are plotted in Figure 5-2. As shown in Figure 5-2, although the temporal relationships show slightly different with using different durations of the time charter rate (*TC*6, *TC*1 and *TC*3), in most cases, the temporal relationships between *NP*, *FP* and *TC* indicate that time charter rate leads either the new-building or the second-hand ship price. Results from *TC*6 for the Capesize carriers and *TC*3 for the Handysize carriers exhibit slightly different. In fact, these two situations are not the common cases because the larger ships (e.g. Capesize carriers) are usually hired for a longer time period and the smaller ones (e.g. Handysize carriers) are more active in a shorter duration.

Figure 5-2: Temporal Relationships among *NP*, *FP* and *TC* in the Dry Bulk Sector



Notes:
1. *NP* and *FP* are used to represent the new-building and 5-year-old second-hand ship prices, while *TC*6, *TC*1 and *TC*3 represents 6-month, 1-year and 3-year time charter rates respectively.
2. The solid line indicates that Granger causality is significant at 1% level, while the dashed line indicates that Granger causality is significant at 5% level.
3. Lead-lag relationships are based on the results in Table 5-6.

A test with using 10-year-old second-hand ship prices is also be conducted[14]. The existence of cointegration are the same as using 5-year-old second-hand ship price in the Capesize and Handysize ship segments, namely cointegration exists for all the carriers. For the Panamax vessels, cointegration exists with 1-year and 3-year time charter rates while no cointegration with 6-month time charter rate.

Granger causality test results are shown in Table 5-7 and Figure 5-2. Clearly, the conclusion that time charter rate leads either the new-building or the second-hand ship price can be hold with *TP* for almost all the ship types hired for different durations (the only exception is *TC*6 for the Capesize carriers). Then it could be concluded that time charter rate responses to the new information more quickly than the ship prices in the dry bulk shipping sector.

Table 5-7: Granger Causality Test Results among *NP*, *TP* and *TC* in the Dry Bulk Sector

Dependent variable	χ^2 Statistics (p-value)	Dependent variable	χ^2 Statistics (p-value)	Dependent variable	χ^2 Statistics (p-value)
Capesize VEC(1) - *NP*, *FP*, *TC*6					
$\triangle NP$	$\triangle FP$ 1.1840(0.2765) $\triangle TC6$ 3.0291(0.0818)	$\triangle FP$	$\triangle NP$ 1.1162(0.2908) $\triangle TC6$ 11.111(0.0009**)	$\triangle TC6$	$\triangle NP$ 4.8439(0.0277*) $\triangle FP$ 0.1265(0.7221)

[14] The cointegration test results are not given because the same methods are used and results show slightly different.

Table 5-7: Granger Causality Test Results among *NP*, *TP* and *TC* in the Dry Bulk Sector (Continued)

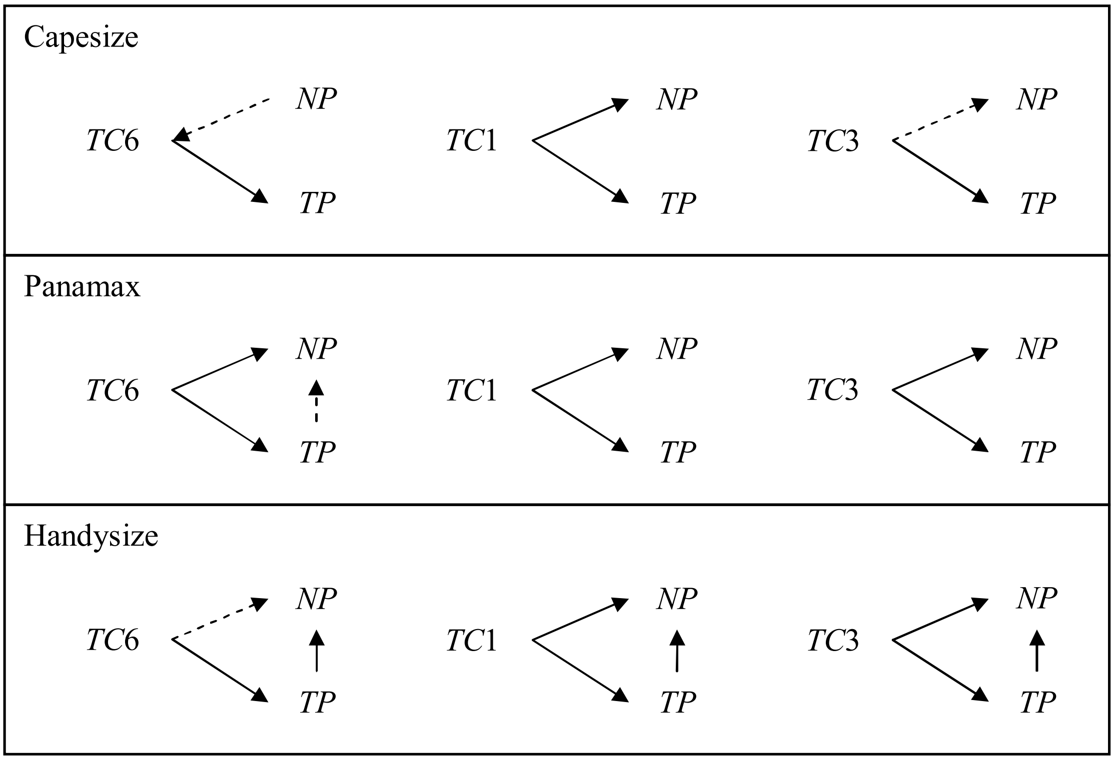
Capesize VEC(1) - *NP*, *TP*, *TC*1					
△*NP*	△*TP* 0.1717(0.6786) △*TC*1 7.4702(0.0063**)	△*TP*	△*NP* 1.8552(0.1732) △*TC*1 20.342(0.0000**)	△*TC*1	△*NP* 3.1321(0.0768) △*TP* 0.6368(0.4249)
Capesize VEC(1) - *NP*, *TP*, *TC*3					
△*NP*	△*TP* 0.6409(0.4234) △*TC*3 4.6967(0.0302*)	△*TP*	△*NP* 1.1196(0.2900) △*TC*3 26.906 (0.0000**)	△*TC*3	△*NP* 0.4239(0.5150) △*TP* 0.3921(0.5312)
Panamax VAR(1) - *NP*, *TP*, *TC*6					
△*NP*	△*TP* 5.3107(0.0212*) △*TC*6 14.921(0.0001**)	△*TP*	△*NP* 1.0327(0.3095) △*TC*6 7.3859(0.0066**)	△*TC*6	△*NP* 0.8569(0.3546) △*TP* 0.9129(0.3393)
Panamax VEC(1) - *NP*, *TP*, *TC*1					
△*NP*	△*TP* 0.5314(0.4660) △*TC*1 26.407(0.0000**)	△*TP*	△*NP* 1.3970(0.2372) △*TC*1 23.922 0.0000**)	△*TC*1	△*NP* 1.7406(0.1871) △*TP* 1.6114(0.2043)
Panamax VEC(1) - *NP*, *TP*, *TC*3					
△*NP*	△*TP* 0.4582(0.4984) △*TC*3 33.647(0.0000**)	△*TP*	△*NP* 1.1394(0.2858) △*TC*3 13.971(0.0002**)	△*TC*3	△*NP* 0.7667(0.3812) △*TP* 3.3552(0.0670)
Handysize VEC(1) - *NP*, *TP*, *TC*6					
△*NP*	△*TP* 11.780(0.0006**) △*TC*6 6.1431(0.0132*)	△*TP*	△*NP* 0.1078(0.7427) △*TC*6 12.703(0.0004**)	△*TC*6	△*NP* 1.3952 (0.2375) △*TP* 2.0483(0.1524)
Handysize VEC(1) - *NP*, *TP*, *TC*1					
△*NP*	△*TP* 8.5248(0.0035**) △*TC*1 13.758(0.0002**)	△*TP*	△*NP* 0.4718(0.4922) △*TC*1 36.767(0.0000**)	△*TC*1	△*NP* 1.7098(0.1910) △*TP* 3.2865(0.0699)

Table 5-7: Granger Causality Test Results among *NP*, *TP* and *TC* in the Dry Bulk Sector (Continued)

Handysize VEC(1) - *NP*, *TP*, *TC*3					
△*NP*	△*TP* 10.962(0.0009**) △*TC*3 12.855(0.0003**)	△*TP*	△*NP* 0.0177(0.8940) △*TC*3 27.423(0.0000**)	△*TC*3	△*NP* 0.6114(0.4342) △*TP* 3.5502(0.0595)

Notes:
1. *NP* and *TP* represent the new-building and 10-year-old second-hand ship prices. *TC*6, *TC*1 *and TC*3 represent 6-month, 1-year and 3-year time charter rates, respectively.
2. * indicates statistical significance at 5% level; ** indicates significant at 1% level.

Figure 5-3: Temporal Relationships among *NP*, *TP* and *TC* in the Dry Bulk Sector



Notes:
1. *NP* and *TP* are used to represent the new-building and 10-year-old second-hand ship prices, while *TC*6, *TC*1 and *TC*3 represents 6-month, 1-year and 3-year time charter rates respectively.
2. The solid line indicates that Granger causality is significant at 1% level, while the dashed line indicates that Granger causality is significant at 5% level.
3. Lead-lag relationships are based on the results in Table 5-7.

5.4 Relationships between the freight and ship markets in the tanker sector

The same testing procedures are conducted in the tanker sector. One special feature in this sector is that ships are usually hired in a longer time period than they are in the dry bulk sector. Thus, the data samples of *TC*6 are not available. As mentioned earlier, since *TC*3 are relatively limited to eliminate shipping cycle problem, *TC*3' are used to denote the samples after enlargement from Jan. 2000.

Table 5-8 below assembles the cointegration test results between *NP*, *FP* and *TC*. As shown in it, results drawn from *TC*1 and *TC*3' are identical for the same ship type. It implies that evidences from *TC*3' is more trustable than *TC*3. Here, the results from *TC*3 are also given for reference. The results from cointegration test appear that *TC*, *NP* and *FP* are only cointegrated in the VLCC ship segment, whereas for the Suezmax and Aframax tankers, no cointegration could be found. To conclude, these three variables are likely to have a long-run relationship for the large ship types (Capesize and VLCC). This may be because the purpose for investing on the large ship types is usually to operate them in the freight market for transportation services. While for the small ship types, it is easier for them to change hand in the second ship market to take the advantage of the second-hand ship price. Overall, results from cointegration test show different structures of the dry bulk and tanker sectors.

Table 5-8: Cointegration Test Results among *NP*, *FP* and *TC* in the Tanker Sector

Variables	Lags	Hypothesized No. of CE(s)	$\lambda_{\max}$	0.05 Critical Value	λ_{trace}	0.05 Critical Value
VLCC						
*TC*1, *NP* and *FP*	*q*=2	None	42.77269**	21.1316	53.86795**	29.7971
		At most 1	11.09247	14.2646	11.09526	15.4947
		At most 2	0.002788	3.84147	0.002788	3.84147
*TC*3', *NP* and *FP*	*q*=2	None	26.44700**	21.1316	38.09448**	29.7971
		At most 1	11.63083	14.2646	11.64747	15.4947
		At most 2	0.016645	3.84147	0.016645	3.84147
*TC*3, *NP* and *FP*	*q*=2	None	25.24427*	21.1316	42.61477**	29.7971
		At most 1	16.90570*	14.2646	17.37051*	15.4947
		At most 2	0.464803	3.84147	0.464803	3.84147
Suezmax						
*TC*1, *NP* and *FP*	*q*=2	None	16.35739	21.1316	23.43648	29.7971
		At most 1	7.077928	14.2646	7.079093	15.4947
		At most 2	0.001166	3.84147	0.001166	3.84147
*TC*3', *NP* and *FP*	*q*=3	None	13.48041	21.1316	21.10283	29.7971
		At most 1	7.563943	14.2646	7.622421	15.4947
		At most 2	0.058478	3.84147	0.058478	3.84147
*TC*3, *NP* and *FP*	*q*=2	None	15.33630	21.1316	25.27856	29.7971
		At most 1	9.334753	14.2646	9.942263	15.4947
		At most 2	0.607510	3.84147	0.607510	3.84147
Aframax						
*TC*1, *NP* and *FP*	*q*=3	None	11.96124	21.1316	17.52544	29.7971
		At most 1	5.261461	14.2646	5.564193	15.4947
		At most 2	0.302733	3.84147	0.302733	3.84147
*TC*3', *NP* and *FP*	*q*=3	None	17.03146	21.1316	24.14568	29.7971
		At most 1	7.047201	14.2646	7.114220	15.4947
		At most 2	0.067019	3.84147	0.067019	3.84147
*TC*3, *NP* and *FP*	*q*=3	None	17.82758	21.1316	22.67374	29.7971
		At most 1	4.003182	14.2646	4.846159	15.4947
		At most 2	0.842976	3.84147	0.842976	3.84147

Notes:

1. *NP* and *FP* represent the new-building and 5-year-old second-hand ship prices. *TC*1, *TC*3 *and TC*3' represent 1-year, 3-year and adjusted 3-year time charter rates, respectively.

2. * indicates statistical significance at 5% level; ** indicates significant at 1% level.

Table 5-9 and Figure 5-4 summarized the Granger causality test results among *TC*, *NP* and *FP*. It appears that the temporal linkages among these three variables are more similar for the Suezmax and Aframax vessels, i.e. *NP* or *TC* leads *FP*. Unlike these two ship segments, it is found that *NP* even leads *TC* (*TC*1 or *TC*3) for the VLCC tankers. This result is different with the general conclusion drawn from the dry bulk sector. At least, the time charter rate is not a good indicator in the VLCC ship segment. Instead, the new-building ship price can be viewed as this leading indicator. Another finding is that *NP* still leads *FP* in this three-variable system. It implies that adding *TC* into the two-variable framework can not change the directions of information flow between *NP* and *FP* in the tanker sector. Overall, results from both cointegration and Granger causality tests exhibit the different structures for the dry bulk and tanker sectors.

Table 5-9: Granger Causality Test Results among *NP*, *FP* and *TC* in the Tanker Sector

Dependent variable	χ^2 Statistics (p-value)	Dependent variable	χ^2 Statistics (p-value)	Dependent variable	χ^2 Statistics (p-value)
VLCC VEC(1) - *NP*, *FP*, *TC*1					
△*NP*	△*FP* 0.4352(0.5094) △*TC*1 0.1651(0.6845)	△*FP*	△*NP* 5.4322(0.0198*) △*TC*1 4.1486 (0.0417*)	△*TC*1	△*NP* 19.662(0.0000**) △*FP* 9.9389(0.0016**)
VLCC VEC(1) - *NP*, *FP*, *TC*3’					
△*NP*	△*FP* 0.0033(0.9542) △*TC*3’ 1.4034(0.2362)	△*FP*	△*NP* 9.2613(0.0023**) △*TC*3’ 3.9142(0.0479*)	△*TC*3’	△*NP* 17.704(0.0000**) △*FP* 7.5564(0.0060**)

Table 5-9: Granger Causality Test Results among *NP*, *FP* and *TC* in the Tanker Sector (Continued)

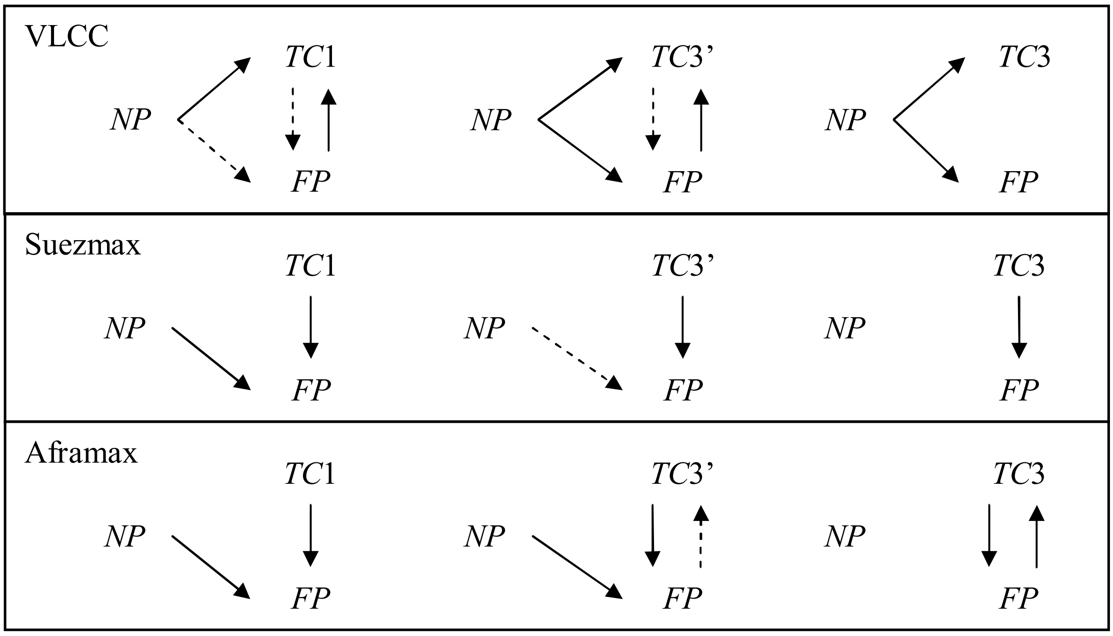
VLCC VEC(1) - *NP*, *FP*, *TC*3					
$\triangle NP$	$\triangle FP$ 0.9709(0.3245)	$\triangle FP$	$\triangle NP$ 14.164(0.0002**)	$\triangle TC3$	$\triangle NP$ 13.085(0.0003**)
	$\triangle TC3$ 0.4886 (0.4846)		$\triangle TC3$ 2.8413(0.0919)		$\triangle FP$ 2.8784(0.0898)
Suezmax VAR(1) - *NP*, *FP*, *TC*1					
$\triangle NP$	$\triangle FP$ 0.9332(0.3340)	$\triangle FP$	$\triangle NP$ 7.7774(0.0053**)	$\triangle TC1$	$\triangle NP$ 0.2555(0.6132)
	$\triangle TC1$ 1.2216(0.2691)		$\triangle TC1$ 28.793(0.0000**)		$\triangle FP$ 0.0805(0.7767)
Suezmax VAR(2) - *NP*, *FP*, *TC*3’					
$\triangle NP$	$\triangle FP$ 1.0395(0.5947)	$\triangle FP$	$\triangle NP$ 6.4404(0.0399*)	$\triangle TC3'$	$\triangle NP$ 2.5267(0.2827)
	$\triangle TC3'$ 5.2375(0.0729)		$\triangle TC3'$ 23.921(0.0000**)		$\triangle FP$ 1.2803(0.5272)
Suezmax VAR(1) - *NP*, *FP*, *TC*3					
$\triangle NP$	$\triangle FP$ 0.0608(0.8052)	$\triangle FP$	$\triangle NP$ 2.2173(0.1365)	$\triangle TC3$	$\triangle NP$ 0.4080(0.5230)
	$\triangle TC3$ 2.7272(0.0986)		$\triangle TC3$ 10.916(0.0010**)		$\triangle FP$ 0.8443(0.3582)
Aframax VAR(2) - *NP*, *FP*, *TC*1					
$\triangle NP$	$\triangle FP$ 2.0393(0.3607)	$\triangle FP$	$\triangle NP$ 11.092 (0.0039**)	$\triangle TC1$	$\triangle NP$ 0.0056(0.9972)
	$\triangle TC1$ 0.9941(0.6083)		$\triangle TC1$ 19.305(0.0001**)		$\triangle FP$ 5.8634(0.0533)
Aframax VAR(2) - *NP*, *FP*, *TC*3’					
$\triangle NP$	$\triangle FP$ 2.5097(0.2851)	$\triangle FP$	$\triangle NP$ 11.032(0.0040**)	$\triangle TC3'$	$\triangle NP$ 2.0009(0.3677)
	$\triangle TC3'$ 0.5446(0.7616)		$\triangle TC3'$ 12.525(0.0019**)		$\triangle FP$ 7.5756(0.0226*)
Suezmax VAR(1) - *NP*, *FP*, *TC*3					
$\triangle NP$	$\triangle FP$ 2.1233(0.3459)	$\triangle FP$	$\triangle NP$ 5.9048(0.0522)	$\triangle TC3$	$\triangle NP$ 3.9707(0.1373)
	$\triangle TC3$ 0.2259(0.8932)		$\triangle TC3$ 10.684(0.0048**)		$\triangle FP$ 12.253(0.0022**)

Notes:

1. *NP* and *FP* represent the new-building and 5-year-old second-hand ship prices. *TC*1, *TC*3 and *TC*3’ represent 1-year, 3-year and adjusted 3-year time charter rates, respectively.

2. * indicates statistical significance at 5% level; ** indicates significant at 1% level.

Figure 5-4: Temporal Relationships among *NP*, *FP* and *TC* in the Tanker Sector



Notes:
1. *NP* and *FP* represent the new-building and 5-year-old second-hand ship prices. *TC*1, *TC*3 *and TC*3' represent 1-year, 3-year and adjusted 3-year time charter rates, respectively.
2. The solid line indicates that Granger causality is significant at 1% level, while the dashed line indicates that Granger causality is significant at 5% level.
3. Lead-lag relationships are based on the results in Table 5-9.

5.5 Comparison of the results from the dry bulk and tanker sectors

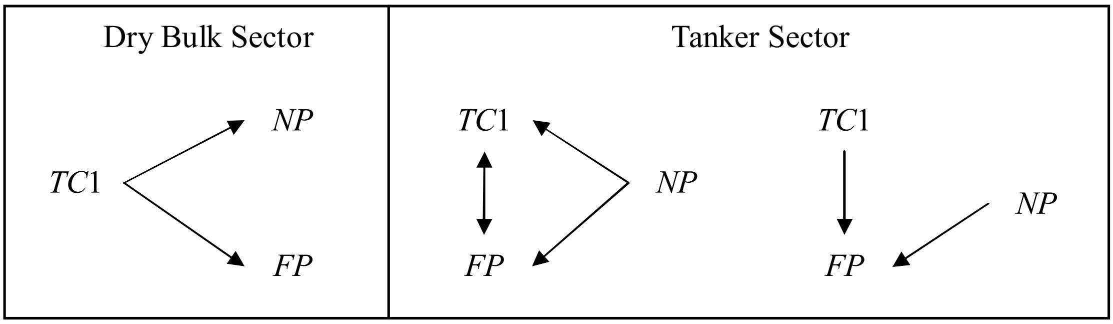
The comparison of the results drawn from the dry bulk and tanker sectors is made next.

First, the results from cointegration test show the similarity and differences for the dry bulk and tanker sectors. For the similarity, the findings of cointegration test suggested that the time charter rate and ship prices are more likely to have a long-run relationship for the large ship types (Capesize and VLCC). However, differences can be concluded that *TC*, *NP* and *FP* tie more closely in the dry bulk sector than in the tanker sector. It implies that the driven factors for these three variables are more likely to be different for the tankers.

Second, the findings from Granger causality test reveal majority differences for the dry bulk and tanker sectors. As discussed earlier, since there are 3 kinds of time charter rate, 2 types of second-hand ship prices and 6 ship types in total, the temporal relationships for three-dimensional system is complicated. In order to simplify the comparison, first, a typical temporal relationship is chosen to represent the most common case in these two shipping sectors. Since the data of *TP* in the tanker sector are limited, *FP* is chosen to represent the second-hand ship price. For the time charter rate, *TC*1 stands for the most common relationships for both the dry bulk and tanker sectors. All the relationships are just considered at 5% significant level.

The simplified temporal relations are summarized in Figure 5-6. For the dry bulk sector, time charter rate can be viewed as an indicator of the international shipping environment because it leads both the new-building and second-hand ship prices. In the counterpart, the figure on the left hand side stands for the VLCC ship segment, while the other one represents Suezmax and Aframax tankers. It can be observed obviously that the temporal relationships in the tanker sector are not as stable as in the dry bulk sector, and those relationships are different with the dry bulk sector. One difference is, for the dry bulk sector, ship prices (*NP* and *FP*) can not lead *TC* but *FP* or *TC* can not leads *NP* in the tanker sector. Another difference is, comparing the results from three-variable with two-variable system, when taking time charter rate into account, the lead-lag relations between the new-building and second-hand prices are seldom affected in the tanker sector. However, in the dry bulk sector, these relations will be eliminated.

Figure 5-5: Typical Relationships among Three Markets in Two Shipping Sectors



Notes:
1. For the tanker sector, the figure above stands for the VLCC ship segment, while the one below represents Suezmax and Aframax tankers.
2. *NP*, *FP* and *TC*1 are used to represent the new-building, 5-year-old second-hand ship prices and 1-year time charter rate, respectively.
3. All of the relationships are considered at 5% level.

The analyses on the temporal relationships are carried out with every pair of the variables. In order to examine which variable can be viewed as a leading indicator, investigation should be conducted on the lead-lag relationships between one variable and the system contained two variables, i.e. relationships between (*NP*, *FP*)&*TC*, (*NP*, *TC*)&*FP*, and (*FP*, *TC*)&*NP*. Taking (*NP*, *FP*)&*TC* as an example, two null hypothesis should be tested. One of them is "(*NP*& *FP*) does not Granger cause *TC*". This test can be carried out with Eviews 6.0. While the other hypothesis is "*TC* does not Granger cause (*NP*& *FP*)" which can not achieve on Eviews 6.0. Then this hypothesis is tested with JMulTi software[15], and this software only suggests *F* statistics. Table 5-10 gives the results of this kind of relationships in two shipping sectors. Figure 5-7 summarizes results of the role played by *FP*, *TC*1 and *NP* in two shipping sectors based on the results in Table 5-10.

As shown in Figure 5-7, *TC*1 leads the system of *NP*&*FP* for all the dry bulk tankers. However, in the tanker sector, *NP* leads the system of *FP*&*TC*1 for all the three ship segments. Therefore, the leading indicators in these two shipping sectors are different. For the dry bulk sector, the time charter rate can be used to forecast the changes of ship prices in the future. However, this indicator is more possible to be played by the new-building ship price in the tanker sector. To this end, the dry bulk and tanker sectors have different linkages of the main shipping markets.

Veenstra (1999) suggested that the causal links in the dry bulk and tanker sector are different because the roles of the second-hand ship price or even the second-hand

[15] JMulTi is used when Eviews can not test the null hypothesis.

ship market. However, this study found that *FP* is in the same status in the dry bulk and tanker sectors from the view of temporal relationships, namely *FP* is leaded by the system of *NP* and *TC*1. Then, the different structures of two shipping sectors may caused by other reasons. From the role of *TC*1 and *NP* in Figure 5-7, it can be noticed that the temporal relationships between *NP* and the two-variable system are just opposite, that is *NP* leads the system of *FP* and *TC*1 in the tanker sector but it is leaded by the *FP*& *TC*1 system in the dry bulk sector. Therefore, there exists the possibility that the different structures of the dry bulk and tanker sectors are caused by the new-building ship market. The order or the new-building business is more active than the transactions of the second-hand ships in the tanker sector.

Table 5-10: Comparison the Role of *NP*, *FP* and *TC*1 in Two Shipping Sectors

Dependent variable	χ^2 and F statistics (p-value)	Dependent variable	χ^2 and F statistics (p-value)	Dependent variable	χ^2 and F statistics (p-value)
Capesize VEC(1) - *NP*, *FP*, *TC*1					
$\triangle NP$	$\triangle FP \& \triangle TC1$ χ^2=18.339 (0.0001**)	$\triangle FP$	$\triangle NP \& \triangle TC1$ χ^2=32.655 (0.0000**)	$\triangle TC1$	$\triangle NP \& \triangle FP$ χ^2=5.2488 (0.0725)
$\triangle FP \& \triangle TC1$	$\triangle NP$ F=1.5863 (0.1764)	$\triangle NP \& \triangle TC1$	$\triangle FP$ F=2.2322 (0.0643)	$\triangle NP \& \triangle FP$	$\triangle TC1$ F=13.2609 (0.0000**)
Panamax VAR(1) - *NP*, *FP*, *TC*1					
$\triangle NP$	$\triangle FP \& \triangle TC1$ χ^2=51.502 (0.0000**)	$\triangle FP$	$\triangle NP \& \triangle TC1$ χ^2=41.171 (0.0000**)	$\triangle TC1$	$\triangle NP \& \triangle FP$ χ^2=4.3001 (0.1165)
$\triangle FP \& \triangle TC1$	$\triangle NP$ F=4.5375 (0.0112*)	$\triangle NP \& \triangle TC1$	$\triangle FP$ F=1.5050 (0.2233)	$\triangle NP \& \triangle FP$	$\triangle TC1$ F=22.8197 (0.0000**)

Table 5-10: Comparison the Role of *NP*, *FP* and *TC*1 in Two Shipping Sectors

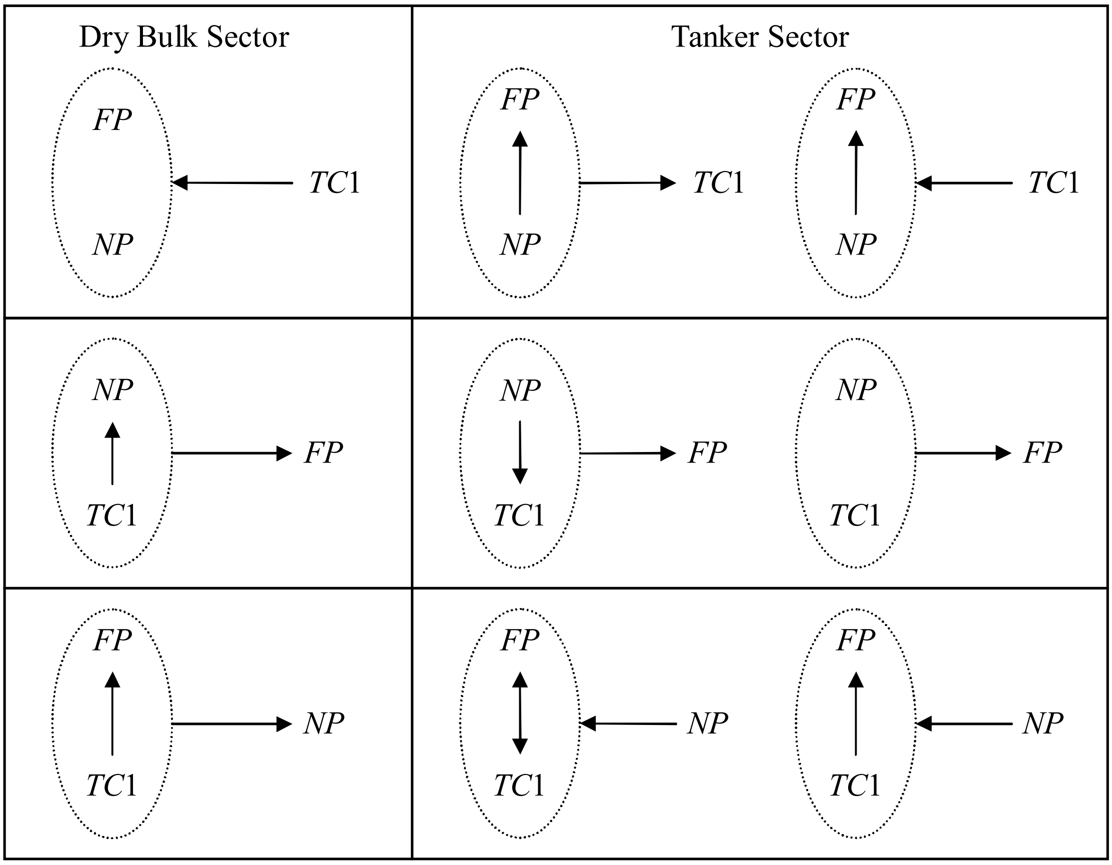
(Continued)

Handysize VEC(1) - *NP*, *FP*, *TC*1					
	△*FP*&△*TC*1		△*NP*&△*TC*1		△*NP*&△*FP*
△*NP*	χ^2 =14.381	△*FP*	χ^2 =22.859	△*TC*1	χ^2 =4.3330
	(0.0008**)		(0.0000**)		(0.1146)
	△*NP*		△*FP*		△*TC*1
△*FP*&△*TC*1	*F*=2.1783	△*NP*&△*TC*1	*F*=1.5897	△*NP*&△*FP*	*F*=9.2308
	(0.0694)		(0.1747)		(0.0000**)
VLCC VEC(1) - *NP*, *FP*, *TC*1					
	△*FP*&△*TC*1		△*NP*&△*TC*1		△*NP*&△*FP*
△*NP*	χ^2 =0.4970	△*FP*	χ^2 =8.8665	△*TC*1	χ^2 =20.637
	(0.7800)		(0.0119*)		(0.0000**)
	△*NP*		△*FP*		△*TC*1
△*FP*&△*TC*1	*F*=7.7886	△*NP*&△*TC*1	*F*=1.1850	△*NP*&△*FP*	*F*=2.8467
	(0.0000**)		(0.3176)		(0.0244*)
Suezmax VAR(1) - *NP*, *FP*, *TC*1					
	△*FP*&△*TC*1		△*NP*&△*TC*1		△*NP*&△*FP*
△*NP*	χ^2 =3.0927	△*FP*	χ^2 =44.469	△*TC*1	χ^2 =0.5138
	(0.2130)		(0.0000**)		(0.7735)
	△*NP*		△*FP*		△*TC*1
△*FP*&△*TC*1	*F*=3.9284	△*NP*&△*TC*1	*F*=0.4963	△*NP*&△*FP*	*F*=14.6324
	(0.0207*)		(0.6093)		(0.0000**)
Aframax VAR(2) - *NP*, *FP*, *TC*1					
	△*FP*&△*TC*1		△*NP*&△*TC*1		△*NP*&△*FP*
△*NP*	χ^2 =4.2240	△*FP*	χ^2 =34.367	△*TC*1	χ^2 =7.7410
	(0.3765)		(0.0000**)		(0.1015)
	△*NP*		△*FP*		△*TC*1
△*FP*&△*TC*1	*F*=3.0256	△*NP*&△*TC*1	*F*=2.1009	△*NP*&△*FP*	*F*=5.3887
	(0.0181*)		(0.0808)		(0.0003**)

Notes:

1. *NP, FP* and *TC*1 denote the new-building, 5-year-old second-hand ship prices and 1-year time charter rate, respectively.
2. * indicates statistical significance at 5% level; ** indicates significant at 1% level.

Figure 5-6: Comparison of the Role Played by *FP*, *TC*1 and *NP* in Two Shipping Sectors



Notes:

1. In the tanker sector, the left figure stands for the VLCC tankers, while the right one represents Suezmax and Aframax tankers.
2. *NP*, *FP* and *TC*1 are used to represent the new-building, 5-year-old second-hand ship prices and 1-year time charter rate, respectively.
3. All the relationships are considered at 5% level and results are based on Table 5-10.

Chapter 6: Conclusions and Limitations

6.1 Conclusions and implications

This thesis represents an attempt to investigate three different but interrelated markets in the international shipping industry, namely the freight market, new-building and second-hand markets. In each market, price was chosen as the key variable to examine the existence of temporal relationships between these variables for three different vessel sizes in both the dry bulk and tanker sectors. The first purpose is to capture the existence of cointegration and temporal relationships between the freight rate and ship prices. The second aim is to compare the different results drawn from the two shipping sectors.

In the first step, this study examines the existence of lead-lag relationship between the monthly new-building and second-hand ship prices (5-year-old and 10-year-old) for three different vessel sizes in both the dry bulk and tanker sectors. Broadly speaking, the evidences from our study show that the new and second-hand ships are not close substitutes, especially in the tanker sector since their prices are not driven by the same trends. Furthermore, these two prices do not react to the new information simultaneously but have a temporal difference, i.e., in most cases, second-hand ship price leads the new-building price in the dry bulk sector, while the opposite conclusion on the lead-lag relation is drawn for the tanker sector. Results for the sub-periods suggest that this lead-lag relationship is not stable over time and the conclusion of the opposite temporal links between the two sectors discussed above can be further confirmed from the data during the booming shipping environments. The contradictory results in two shipping sectors may be explained by the fact that the average new-building ship price in the dry bulk sector significantly leads the new-building ship price in the tanker sector. This offers some implications to investors that the dry bulk ship price may be taken as an important signal.

This study then extends the examination to the temporal linkage between the freight and ship (new-building and second-hand) markets in both dry bulk and tanker sectors. Evidences from the cointegration test show that the new-building, second-hand and freight markets tie more closely in the dry bulk sector than in the tanker sector. The evidences from temporal relationships indicate that the linkages among these markets are differed in these two shipping sectors. For the dry bulk sector, the time charter rate is a good indicator to forecast the changes of other variables. In the counterpart of the tanker sector, this indicator is more likely to be played by the new-building ship price. In addition, this study suggests that the different structures for the dry bulk and tanker sectors are more possible to be caused by the new-building ship market.

This research focused on the temporal relationships between three main shipping markets in two shipping sectors. The findings suggest that the investment timing and the important leading indicator are different for the dry bulk and tanker shipping. The ship-owners and investors will benefit from knowing this kind of information since it captures the future changes of the shipping environment. Specifically, the evidences in the tanker sector show that the freight rate is not a good indicator to predict the ship price patterns in the future. This finding reminds the investors in the tanker shipping not to depend on the information of the freight rate on their investment decision.

This study makes a first concern on the differences for the dry bulk and tanker sectors. Research on these differences is important because the differences remind the investors not to use the investment strategies in the dry bulk shipping directly to the tanker shipping. Theoretically, past studies usually considered the same function or the same determinants for the dry bulk and tanker shipping. However, these two sectors have sufficient differences. Researchers should re-think the factors chosen in tanker shipping in future studies.

All the findings in this thesis suggest that the temporal relationships between the freight rate and ship prices or even the freight and ship markets more complex than previously expected. The economic structures are obviously distinct for the dry bulk and tanker sectors and investigations should be conducted separately for the two sectors in the future.

6.2 Limitations

The first limitation of this study is, for the three-variable system, the methodology for examining the temporal relationships is not fulfilled. For example, when considering the relationships among *NP*, *FP* and *TC*1, if the lag length for this system is chosen as 1 month, then the temporal relations for the three variables are all considered within 1 month. However, the optimal lead-lag time length for two variables, such as *NP* and *FP*, may be within 2 to 3 months. The model of three-variable system did not consider this situation.

The second limitation is also related to the methodology. For the issue on the lead-lag relationship among a number of variables, it is usually excluded other factors from the model. Considering all the factors in VAR or VEC model makes the explanation complicated. Thus, further development is needed for the methodology part.

The third limitation is this study did not consider the sudden change to the data series which may has a great influence on the lead-lag relations. It could include the dummy variables to eliminate this influence in the future.

6.3 Future studies

For the future studies, since either the reality phenomena or the empirical results have already revealed the special economic structure of tanker sector to some extent, it is worth to investigate the tanker sector separately to find why it exhibits the distinct features, what kind of reasons behind it. Two aspects are considered to be examined as the possible reasons in the future.

The first one is related to the freight market. It is well known that in the tanker sector, supply is overcapacity for a long time period. A prevalent belief for supply/demand is that supply should adjust to demand over time. For the tanker sector, the imbalance between supply and demand is severe, so it’s hard to set the supply to the demand. The disequilibrium supply/demand model could be considered to study the determinants on the freight rate. Another possible reasons in the freight market is the volatility of different durations of freight rates. A general rule is that a long-term time charter is smoother than a short-term one. Tankers’ time charters tended towards longer terms than the dry bulk carriers. So it may be one of the reason caused the tanker shipping different.

The second direction is to examine the different characteristics of the ship markets. Ship markets here include the new-building and second-hand ship markets. In tanker shipping, a number of the ship-owners are the large oil companies. They have their own fleet to transport the oils which makes the second-hand ship market to be inactive in tanker shipping. Because the large oil companies are more willing to operate their ships in the freight market for their oil transportation rather than to sell the ships in the second-hand market to take the advantages of ship prices. To this end, the liquidity of the second-hand ships is lower in the tanker shipping than it is in dry bulk shipping.

The second extension is on how the findings in this study affected by taking into account of the differences of geographical influence - specific shipping routes. In reality, the level of the freight rates and the relationships among the shipping markets may vary across different major shipping routes from one region to another. It's worth to examine whether the findings can be affected by the geographical influence.

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