Modelling and Forecasting in the Dry Bulk Shipping Market

(Modelleren en Voorspellen in de Droge Bulk Markt voor Scheepvaart)

Proefschrift

ter verkrijging van de graad van doctor
aan de Technische Universiteit Delft,
op gezag van de Rector Magnificus prof.ir.K.C.A.M.Luyben,
voorzitter van het College voor Promoties,
in het openbaar te verdedigen op
vrijdag 9 december 2011 om 10.00 uur

door

Shun CHEN

Master of Science, Shanghai Maritime University
geboren te Changzhou City, Jiangsu Provincie, China

Dit proefschrift is goedgekeurd door de promotoren:
Prof. dr. H.Meersman
Prof. ir. J.J.Hopman

Samenstelling promotiecommissie:

Rector Magnificus	voorzitter
Prof. ir. J.J. Hopman	Technische Universiteit Delft, promotor
Prof. dr. H.Meersman	Universiteit Antwerpen, promotor
Prof. dr. S.P. Strandenes	Norwegian School of Economics and Business Administration
Prof. dr. C. Th. Grammenos	Cass Business School
Prof. dr. E. van de Voorde	Universiteit Antwerpen
Prof. ir. J.C. Rijsenbrij	Technische Universiteit Delft
Ir. J.W. Frouws	Technische Universiteit Delft
Prof.dr.ir.L.A.Tavasszy	Technische Universiteit Delft (Reserve)

ISBN: 978-90-8570-421-8

Published and distributed by Shun Chen
E-mail: shunchen@shmtu.edu.cn

Cover designer: Qinhuai CAI

Printed in the Netherlands by CPI Wöhrmann Print Service

To my family

Acknowledgements

When I worked as a lecturer at Shanghai Maritime University of China, I never thought that I would do my PhD research in a country almost ten thousand kilometers away from home. But one day in 2006, I was told by my colleague Prof. Zhao Gang of Shanghai Maritime University that there was a chance to go abroad for PhD study. Based on the contacts Mr. Zhao Gang gave me, I called Mr. Chen Keqiang, an associate professor at Wuhan University of Technology for more information, and eventually I got in contact with Mr. Kees Dirkse, an assistant professor at the Department of Marine and Transport Technology (MTT) in Delft University of Technology (TU Delft). It's the first time I have known by Kees Dirkse that this PhD study is a jointly program between Chinese Scholarship Council and TU Delft and the application to both sides for this PhD program is needed. Then in a chilly winter of early 2007, Prof. Hans Hopman, the head of the section of Ship Design, Production and Operation at the department of MTT, and Mr. Kees Dirkse flew to Shanghai for the interview, and eventually I was offered the opportunity to study in TU Delft in Oct 2007. I therefore owe a great deal to Mr. Zhao Gang, Chen Keqiang, Hans Hopman and Kees Dirkse, for their assistance in my way to the nice Delft.

It is widely accepted that Ph.D. research is never a bed of roses, but a process filled with challenges, sorrows, frustrations and joys. Undergoing the research has an inevitable effect on shaping my personality. To all those who assisted and supported me to complete this process I am greatly indebted.

First and foremost I would like to thank my two promoters Professor Hilde Meersman and Professor Hans Hopman. Hilde Meersman is a pretty and graceful lady. I thank her for guiding me into the fascinating world of econometrics and shaping all the econometric parts in my dissertation, including econometric models and empirical work. I value many discussions we had and benefit a great deal from her intensive knowledge of econometrics, her rigorous scientific style and the inspiring ideas. Her great effort, warmly support and encouragement during my research and my life are always appreciated. I also thank Hans Hopman for bringing me to TU Delft and for offering the great freedom and support during my research, so that I have the freedom to attend various international conferences and seminars, which are very helpful for my studies.

Great thanks are given to Professor Eddy van de Voorde and Mr. Koos Frouws. I thank Prof. Eddy van de Voorde for having more faith in my abilities than I myself had on occasions, and his trust and encouragement always gave me the faith to conquer many difficulties in my work. Furthermore, I am deeply impressed by his extensive knowledge of shipping economics and his passionate dedication to science, which definitely has a substantial effect on me as a researcher. Koos Frouws is my daily advisor. I would like to thank him for teaching me patiently much knowledge of ship design and ship engineering, which looks a little bit strange for me, a girl with the background of shipping economics. Grasping this knowledge can make me dig deeper in the cross field of shipping economics and technology, where we collaborate closely and create some interesting papers. I will always remember the fun we argued and debated for many issues, from research problems to social, cultural and political topics, and also the fun we had in places where we attended conferences like Antwerp and Lisbon.

Then there are friends, colleagues and family I would like to thank for their support. I am grateful to many friends and colleagues in Delft, especially the group of Chinese Ph.D. candidates, who came to Delft in the same year as I did. We can share the experience, sorrows and joys gained from research, and we share various information of living in Delft as well. With them, my life in Delft becomes easy, interesting and vigorous. Special thanks are due to my roommates Zheng Wei and Li Ziru, who live with me in a big apartment like a family during the past years. These two younger sisters brought many joys and laughs to me and always let me feel very warm in my heart.

I am greatly indebted to Chenli, the director of Chinica Shipbrokers Ltd in Shanghai, for his substantial support in my research not only in shanghai, but also in the Netherlands. He assisted me directly and indirectly to find an appropriate topic of studying the dry bulk shipping market, and my research is not only backed by his keen insights, the valuable experience and his intensive knowledge of the dry bulk market, but supported by his resources as well.

No words can adequately express my gratitude to my parents, Chen Jinhuo and Wang Suofeng, and my parents in law, Cheng Hanqing and Mao Jinyu, for their continuously unconditional love, care and support.

Last, but by no means least, I would like to thank my husband Cheng Liang for his devoted love, understanding and unfailing support to me, for his assistance in collecting and sorting numerous data for me without any complaining even when he is very busy, for his tolerance with my bad temper when I am frustrated by tough issues in the research, and for his sharing my sorrows and joys. Without his support I would never have been able to finish this dissertation.

Preface

It’s widely accepted that the dry bulk shipping, the major component of the world shipping industry, has been recognized as highly risky and volatile, since it is subject to a number of uncertainties, ranging from geopolitical shocks and the ever-changing world economy to fleet changes and the sensitive market sentiment. This fascinating shipping sector, therefore, has always been one of the most concerned topics of academics. The majority of studies with dry bulk shipping related subjects can be found in 1980s and 1990s, and a limited number of studies are seen in 2000s. When the market started a strong upward trend in 2003 and afterwards underwent drastic ups and downs till now, the market conditions have experienced considerable changes characterized as extremely volatile, higher speculative and more sensitive to external shocks. Under these circumstances, this dissertation makes an attempt to model the price behavior and forecast prices in the freight market, the newbuilding ship market and the second-hand ship market, through an extensive investigation of the dry bulk shipping market over the period from 1950 to 2010.

The extensive analysis is carried out in diverse sub-markets, on diverse trading routes, over different market conditions and for different aspects of the dry bulk vessels.

Specifically, three types of sub-markets have been investigated. The first type is distinguished in terms of economic variables, including the freight market, the newbuilding market and the second-hand ship market; the second in terms of different ship sizes, including Capesize, Panamax and Handymax vessels; and the last is distinguished as the physical market and the forward market.

Then, chartering prices *on four major trading routes are examined in the freight* market, namely the transatlantic, the fronthaul, the transpacific and the backhaul. Ship-owners or charterers’ preference and their market strategies, as well as the interactions of demand and tonnage supply on different trading areas all have impacts on prices at each route.

Furthermore, if there seems to be structural breaks over the investigated period, the period can be split into several sub-periods, over which no structural breaks are detected, and the analysis is then implemented at each sub-period.

Finally, the investigation is made not only on the economic performance, but also on the technical performance of dry bulk vessels. For instance, the relationships between the economic performance and the technical innovations of dry bulk ships, and the service-oriented optimal ship designs are both discussed in detail in this thesis. It’s crucial for ship-owners or ship operators to know changes in some technical parameters of dry bulk vessels and their impacts on the economic performance of ship operation, because technical performance directly leads to the operational earnings. And it is also very important for ship-owners to know the influence of different main design parameters on the economic performance in ship operation, because bad ship designs are always not uncommon.

The research is primarily quantitative with case studies and the modelling strategy mainly makes use of econometric time series models, such as the Vector Error Correction Model, the Vector Autoregressive Model, the Autoregressive Moving Average Model and their extensions, which are used to investigate dynamic volatilities, interrelationships between variables or between sub-markets, and to make the prediction of prices. Apart from econometric models, economic models and engineering/technical studies are employed as well to analyze economic and technical issues. Furthermore, annual, monthly and daily figures are used in various models for different research issues.

The research experience, the knowledge and lessons learned from this PhD project will definitely be helpful to me for further studies in the dry bulk shipping sector or may serve as an inspiration for the similar studies in other sectors, such as tanker shipping and liner shipping. It is hoped that modelling techniques, the qualitative and quantitative studies in this thesis may provide useful information for market players, such as ship owners and charterers to make the well-founded decisions on the ship operation, the chartering business of ships, the sale and purchase of ships, or other investment activities.

Shun Chen
Delft, June 2011

Contents

List of Acronyms

ADF	Augmented Dickey and Fuller
AIC	Akaike Information Criterion
ARCH	Autoregressive Conditional Heteroskedasticity
ARMA	Autoregressive Moving Average
ARIMA	Autoregressive Integrated Moving Average
B	Breadth of the vessel
BCOI	London Brent Crude Oil Index
BDI	Baltic Dry Index
BCI	Baltic Capesize Index
BHI	Baltic Handysize Index
BHMI	Baltic Handymax Index
BPI	Baltic Panamax Index
BH	Back Haul
BIFFEX	Baltic International Freight Futures Exchange
CAN	Canadian Dollar
Cb	Block Coefficient
CHF	Swiss Franc
CIF	Cost, Insurance and Freight
D	Depth of the vessel
DWT	Deadweight
ECT	Error Correction Term
ECU	European Currency Unit
EMH	Efficient Market Hypothesis
EGARCH	Exponential Generalised Autoregressive Conditional Heteroskedasticity
FFA	Freight Forward Agreements
FH	Front Haul
GBP	Great British Pound
GARCH	Generalised Autoregressive Conditional Heteroskedasticity
IMF	International Monetary Fund
IFO	Intermediate Fuel Oil
J-B	Jarque-Bera
JPY	Japanese Yen

List of Acronyms

LM	Lagrange Multiplier
LR	Likelihood Ratio
LIBOR	London Interbank Offered Rate
LOA	Length Overall
Lpp	Length between perpendiculars
Lwl	Length at the waterline
MDO	Marine Diesel Oil
MAE	Mean Absolute Error
MT	Metric Ton
OPEC	Organization of Petroleum Exporting Countries
OLS	Ordinary Least Squares
MCR	Maximum Continuous Rating
PP	Philips-Perron
PFS	Perfect Foresight Spread
RE	Rational Expectations
RMSE	Root Mean Square Error Metric
RPM	Rotations Per Minute
RW	Random Walk
SARMA	Seasonal-Autoregressive Moving Average
SBIC	Schwarz Bayesian Information Criterion
SEK	Swedish Krona
SPI	S&P500 Composite Index
SPCI	S&P500 Commodity Index
SURE	Seemingly Unrelated Regressions Estimation
T	Draft of the vessel
TA	Trans Atlantic
TP	Trans Pacific
TC	Time Charter
TCE	Time Charter Equivalent
TCT	Time Charter on Trip Basis
USG	US Gulf
VAR	Vector Autoregressive
VECM	Vector Error Correction Model
WTI	West Texas Intermediate

List of Figures

List of Tables

Chapter 1. Introduction

It is well recognized that the shipping market, particularly the bulk shipping market, is extremely volatile, because it is a global business, influenced by political shocks and economic fluctuations around the world. As Veenstra (1999) points out that many markets exist in shipping for various types of transportation services, for ships traded, for shipping related services such as finance, insurance and bulk fuel, and for shipping related services in port. It is an impossible task to examine all of the shipping industry in this dissertation due to the limited time, the scope, objectives, limitations and the structure, therefore, will be discussed clearly here. Furthermore, basic elements in the dry bulk shipping and definitions of different dry bulk shipping segments will be described in this chapter, constituting the economic background to the whole research.

1.1. Definitions of dry bulk shipping

The marine industry is an essential link in the international trade, with ocean-going vessels representing the most efficient, and often the only method of transporting large volumes of basic commodities and finished products. The bulk shipping most often is defined as the transportation of homogenous bulk cargoes by bulk vessels on an irregular scheduled line, as discussed in Veenstra (1999).

1.1.1. Dry bulk cargoes and vessels

Dry bulk shipping deals with the transportation of dry bulk cargoes, generally categorized as either major bulks or minor bulks. Major bulk cargoes constitute the vast majority of dry bulk cargoes by weight, and includes, among others, iron ore, coal and grain. Minor bulk cargoes include products such as agricultural products, mineral cargoes (including metal concentrates), cement, forest products and steel products.

In 2010, the seaborne trade volume of major bulk cargoes reached 2340 million tons, comprising 71% of all seaborne trade of dry bulk cargoes, according to the database of Clarkson research studies (2010). Among all the dry bulk trade, approximately 984 million tons of iron ore was traded worldwide, about 30% of the total, with the main importers being China, Japan and the European Union. The main producers and exporters of iron ore are Australia, Brazil and India. Secondly, the seaborne trade volume of coal in 2010 was 912 million tons, accounting for about 28% of the total. An increase in the seaborne transportation of coking coal has been primarily driven by an increase in the steel production. Currently, major importers of coking coal are Asia, including Japan, India, China, South Korea and Western Europe. Australia provides a significant amount of coking coal to Asia, while South Africa, the United States and Canada are major sources for Western Europe. Furthermore, in the global market for steam coal, Japan, China, South Korea and India are major importers. The major exporters include Indonesia, Australia, South Africa, Russia and Columbia. Thirdly, the seaborne trade volume of grain in 2010 was 343 million tons, accounting for 10.4% of the total. The total grain production is dominated by the United States. Argentina is the second largest producer followed by Canada and Australia. In terms of imports, the Asia region ranks first, followed by the Middle East, Africa and Latin America.

Apart from main bulk cargoes, the seaborne trade volume of minor bulk cargoes was 955 million tons, comprising 29% of all the seaborne dry bulk trade, based on figures from Clarkson research studies (2010).

Dry bulk vessels

There are various ways to define bulk carriers. For example, the International Convention for the Safety of Life at Sea defines a bulk carrier as ‘a ship constructed with a single deck, top side tanks and hopper side tanks in cargo spaces and intended to primarily carry dry cargo in bulk; an ore carrier; or a combination carrier.’ However, most classification societies use a broader definition where a bulker is any ship that carries dry unpackaged goods.

At the end of 2010, dry bulk carriers represent 35.5% of the world fleet in terms of tonnage and 9% in terms of the number of vessels. The world's dry bulk fleet includes 7,300 ships with a total capacity of 459.3 million tons. Due to the economies of scale, dry bulk carriers became larger and more specialized.

In terms of deadweight, the worldwide dry bulk carrier fleet subdivides into four vessel size categories, which are based on the cargo carrying capacity. The first class size is Capesize vessels. The traditional definition of a Capesize bulk carrier, in terms of deadweight, is over 80,000 dwt. However, the sector is changing. Because there have been a number of new super-Panamaxes ordered, which are 82,000 dwt to 85,000 dwt and are able to transit the Panama Canal with a full cargo, a more modern definition of a Capesize would be based on vessels over 100,000 dwt. The Capesize sector focuses on the long haul iron ore and coal trade routes. Due to the size of Capesize vessels there are only a comparatively small number of ports around the world with the infrastructure to accommodate them.

The second class size is Panamax vessels. Panamax vessels between 60,000 dwt and 100,000 dwt are defined as those with the maximum beam (width) of 32.2 meters permitted to transit the Panama Canal, carry coal, grain, iron ore and, to a lesser extent, minor bulks.

The third class size is Handymax vessels, which are between 30,000 dwt and 60,000 dwt. The Handymax sector operates in a large number of geographically dispersed global trades, mainly carrying grains and minor bulks. Vessels less than 60,000 dwt are built with on-board cranes that enable them to load and discharge cargo in countries and ports with the limited infrastructure.

The smallest class size is Handysize vessels up to 30,000 dwt, which carry exclusively minor bulk cargoes. Historically, the Handysize dry bulk carrier sector was seen as the most versatile. Increasingly, however, this has become more of a regional trading. The vessels are well suited for small ports with length and draft restrictions and also lacking infrastructure.

The supply of dry bulk carriers is affected by vessel deliveries and the loss of existing vessels through scrapping or other circumstances requiring removal. It is not only a result of the number of ships in service, but also the operating efficiency of the worldwide fleet. For example, port congestion can absorb the additional tonnage and therefore can tighten the underlying supply/demand balance.

Three types of main cargoes and major trading routes that dry bulk vessels serve are listed in Table 1.1. Some information in this table is acquired through interviews with shipbrokers, and the other is from Grammenos (2010).

Table 1.1: Different types of bulk carriers with main cargoes and major trading routes

Dry bulk carriers	Commodities		
	Iron ore	Coal	Grain
Capesize	70%-80%	30%-40%	0-5%
Panamax	10%-20%	40%-50%	40%-50%
Handymax/Handy	10%	10%-20%	45%-55%
	Major trading routes		
Capesize	West Australia to Western Europe West Australia to Far East Brazil to Western Europe Brazil to the Far East	East Australia to Western Europe East Australia to Far East South Africa to Western Europe South Africa to Far East	Argentina to Near East and East Europe
Panamax	West Australia to Western Europe West Australia to Far East Brazil to Western Europe Brazil to Far East	North America to Western Europe North America to Far East South Africa to Western Europe South Africa to Far East	North America to Western Europe North America to Far East North America to Near East
Handymax/Handy	India to Far East North America to Far East West Africa to Western Europe	South Africa to Far East South Africa to Europe	North America to Western Europe North America to Africa Australia to Far East

Source: Grammenos (2010) and interviews with shipbrokers

1.1.2. Dry bulk markets

Basically, there are three general types of shipping markets, as suggested by Veenstra (1999).

- Freight markets
- Ship markets
- Maritime service markets

The first type contains markets where freight or charter contracts are traded; the second contains markets where ships are traded and the third includes markets where maritime services, such as finance, insurance and management are traded. Because the first two types of markets are quite uniform in an economic sense and the third one is not, the maritime service markets are not the focus of this dissertation, while charter markets and ship markets are.

In the freight markets, a sub division can be made based on different types of contracts, including the spot market, the period market and the future/forward market. In light of the substantially increasing influence of the freight forward agreement on the spot freight market, the freight forward market is incorporated into the analysis of the freight market, while freight options, freight futures, etc. are not. Each sub market can also be divided by different types of vessels, such as Capesize, Panamax and Handymax.

In the ship markets, a sub-division can also be made by different ship transaction parties, namely the newbuilding market, the second-hand market and the scrapping market. A further division can also be seen in each sub markets by different types of vessels, such as Capesize, Panamax and Handymax vessels.

Consequently, economic features of maritime variables in major markets in each ship size are extensively discussed in the thesis, including the freight market, the freight forward market, the newbuilding market, the second-hand market and the scrapping market. Because the same companies are trading in these four or five shipping markets, their activities are closely interrelated through economic relations. The relations between these markets are thought of influence of the one market on the development of another, which can be illustrated as Figure 1.1.

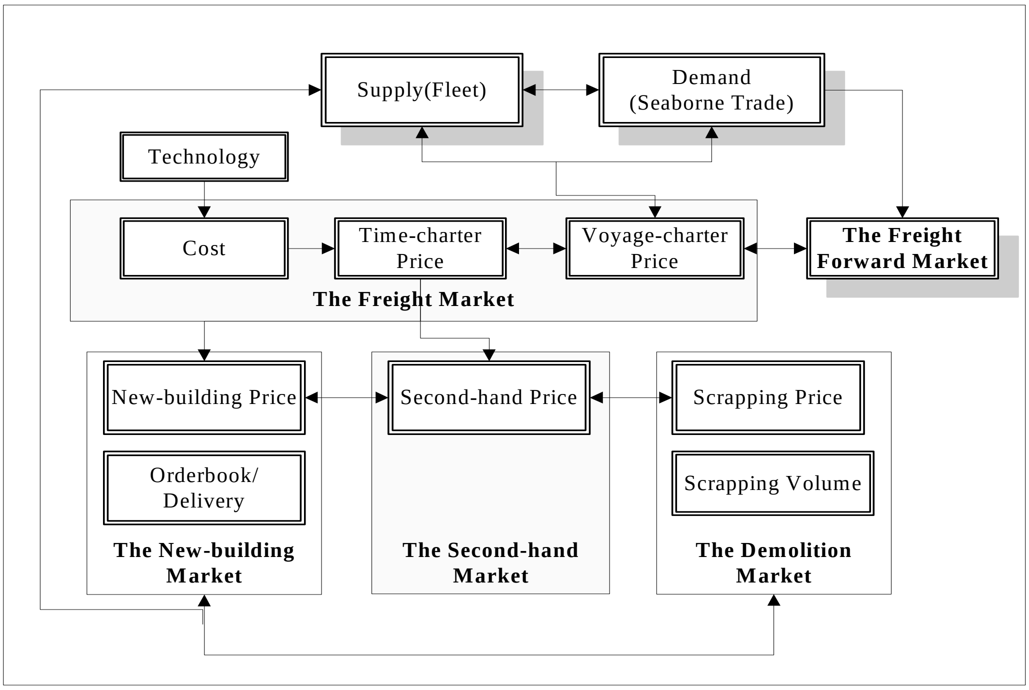

Figure 1.1: Economic relations between markets in the dry bulk shipping

♦ *Firstly, a lead-lag relationship exists between the freight market and the freight derivatives market*

Because prices in the freight derivatives market imply the expectation of market players about future movements in the spot market, changes in returns and volatilities in the forward market will be spilled over to the freight market and will influence the market sentiment and activities, causing a subsequent increase or decrease of spot prices.

The freight rates and freight derivatives rates are basically determined by the market fundamentals, but a distinct difference can be found between these two markets.

♦ *Secondly, there are significant influences of the freight market on the ship markets*

The ups and downs of time charter rates in the freight market are the primary mechanism driving activities of market investors. When the freight market is in an upward trend, the effect will be transmitted into the new-building market and ship-owners will start ordering new ships, while a continuously downward trend in the freight market will possibly cause delay in delivery of new ships or order cancellations.

Changes of time charter rates in the freight market also influence the prices of second-hand ships, due to changes in the expected earnings.

Furthermore, old or obsolete ships will be scrapped in a strongly weak freight market, especially during a recession. The new-building market and the demolition market together form the changes in the supply of the freight market.

♦ *Finally, three ship markets are linked through economic relationships*

High prices in the second-hand market will attract ship-owners to order new ships, while a full orderbook in the new-building market will drive up second-hand prices.

Decisions to scrap ships are also affected by second-hand ship values. If the scrapping value is higher than the second-hand value, old ships will be scrapped.

Furthermore, the new-building price or the second-hand price can be determined through a net present value relation, as the sum of the expected future earnings, the expected scrapped price and a risk premium, if any.

Each of these central markets can also be divided into segments categorized by ship type: Capesize, Panamax, Handymax and Handy. Dynamics in each market differ with each ship type. Though dry bulk vessels nowadays are standardized vessels, different quality of ships measured by major technical indicators, such as deadweight, main dimensions, speed and the fuel consumption, still has a significant impact on the earnings potential during ship operation. The different quality of a ship can be evaluated by the economic performance of a ship.

1.2. Scope, objectives and data issues

The shipping operation consists of a great number of different goods, which require the good, safe and adequate transportation services. This dissertation cannot investigate the whole of the shipping industry and only focuses on the dry bulk shipping. In the dry bulk shipping, different services and goods are traded in different markets. Those markets, at the center of the economic activity of dry bulk shipping, must be captured.

1.2.1. Scope

It is known in Section 1.1 that generally there are three types of shipping markets, the freight market, the ship market and the maritime service market. The core shipping markets have to deal with the actual shipping service and actual ships, see Veenstra (1999). The freight market and the ship market, trading in different commodities are therefore the main focuses of the thesis, which can be seen specifically as follows.

♦ *Focusing on the freight market, the freight forward market, the new-building market and the second-hand market in the dry bulk shipping*

The freight market trades in the sea transport of commodities and deals with ships for hire; the sale and purchase market trades second-hand ships; the new-building market trades new ships, and the demolition market trades old ships for scrap.

As risk management becomes extremely important in the dry bulk shipping industry characterized as highly volatile and capital intensive, the freight derivatives contracts play as a mechanism to offset/hedge freight risks in the spot market, which has been increasingly influenced by the freight derivatives market. In addition to the spot freight market and ship markets, the freight forward market has been included into the research to help explain the price fluctuations and to get the better understanding of the risk control in the spot freight market.

Much of the thesis deals with the analysis of economic processes in the freight market, the freight derivatives market, the new-building market, the second-hand ship market, and to a lesser extent, with the ship demolition market, due to the smaller business of the scrap market and the less important economic role in the dry bulk shipping, compared to the other two ship markets.

♦ *Focusing on Capesize, Panamax and Handymax segments, Handysize out of scope*

Each market can be further distinguished by different ship sizes, namely Capesize, Panamax, Handymax and Handy. Because the seaborne trade of major dry bulks accounts for around 70% of all dry bulks, as stated in Section 1.1, the whole of the research deals with Capesize, Panamax and Handymax, three major types of dry bulk vessels among all, which are used to be engaged in the transportation of main dry bulks. The bulk market for the Handy is out of our research.

♦ *Focusing on not only the economic performance, but also the technical specifications of ships*

With regards to technical innovations in the dry bulk shipping, the thesis makes an examination on impacts of technical changes on the economic performance of ships and makes an attempt to achieve the optimum ship designs based on specific service requirements. As for changes in the technology of ships, the thesis focuses on main technical parameters of ships, including the speed, deadweight, lightweight and fuel consumption, the most concerned issues for ship-owners. It's the first time, to our knowledge, that this kind of research has been made systematically.

Because our research mainly deals with the dry bulk market and dry bulk vessels in the dry bulk shipping industry, influences of technical changes on dry bulk terminals fall out of the scope.

♦ *Primarily making use of time series models and their extensions, instead of structural models*

The modelling and forecasting techniques in this thesis mainly make use of time series models, instead of structural models, partly because it is very difficult to get all of the information and data needed in the structural models. Additionally, for the purpose of the prediction, sometimes it may be even more difficult to forecast the explanatory variables than the explained variables, which will make the prediction of the explained variables very tough.

Under these circumstances, time series models may be superior to structural ones. The extended time series models are considered as well in this thesis, into which some crucial exogenous variables are incorporated, based on the analysis of the market dynamics and the basic causal-effect relationship among variables. Apart from time series models, other economic and engineering approaches are employed, such as the Monte-Carlo simulation and the power estimation approach. This dissertation puts more efforts on the market mechanism and price dynamics, than on forecasting techniques, because the reliable forecast cannot be made without the better understanding of market structure features.

1.2.2. Objectives

The extensive investigation on the dry bulk shipping market in this thesis attempts to attain two main objectives, which can be seen as follows:

- The first one is to propose a framework for analyzing and modelling the economic processes of various variables in the dry bulk shipping market, by making use of modern econometric techniques and other economic approaches, used for the risk assessment and control of ship owners and charterers during the ship operation, the ship chartering and the ship trading activities.

- The other is to offer superior forecasts of prices in the freight market and ship markets by improving the forecasting capabilities of some forecasting models based on the extensive and in-depth investigation of market dynamics and relationships among variables.

This dissertation concentrates on the modern time series modelling, coupling with the proper attention to the underlying structure features and economic activities between variables and between markets. The applications of models are made at a disaggregated level for different types of dry bulk vessels, on different trading routes and for different markets. This approach as such, therefore, allows for modelling the dry bulk market in a much more detailed way.

Apart from the economics of dry bulk shipping, our attention has also been given to the economic and technical performance of dry bulk ships by measuring effects of technological innovations on the economic performance of ships. The combined modelling strategies in this thesis therefore aim for the visualization of the underlying economic mechanism of the dry bulk shipping market and the clarification of relations between the technical and the economic performance of dry bulk ships.

The improved understanding of the pricing dynamics and the market mechanism provides a solid basis for efficient decisions of asset play and normal operations, and may be helpful in the evaluation and control of diverse risks in the dry bulk shipping industry.

1.2.3. Data related issues

It is a time consuming and tough task to collect and analyze data, not only because of the limited data sources, but also of the consistency and the quality of the data. Several issues regarding data handling will be clarified here.

Data sources

The first is about data sources. Most of the shipping related data and the economy related data in econometric models are obtained from Clarkson research studies, also known as Clarkson Intelligence Network, which is regarded as the most complete and professional database among all and is used widely by researchers in the bulk shipping industry. Other sources for these data include various volumes of Lloyd's shipping economists and Baltic Exchange. The careful attention has been made to the possible data discrepancies of different sources. Shipping related data include voyage rates, time charter rates, second-hand ship prices, newbuilding ship prices, scrap prices, bunker prices, fleet capacity, orderbook, deliveries and demolition volumes. The economy related data cover the GDP growth rates and the industrial production figures of different countries and areas, the seaborne trade volumes, crude oil prices, steel prices, exchange rates and interest rates.

Ship related data, such as speed, deadweight, lightweight and the fuel consumption are collected from Clarkson intelligence network, the journal of Lloyd's ship register and the journal of the Significant Ships. Additionally, Chinica Shipbrokers Ltd., a futures company in shanghai, Wilhelmsen ships service Ltd. and ONADA are also sources of some data. Additional information on the chapter-specific data is given on the data description of each chapter.

Due to improvements in the data availability, all the time series research in this dissertation deals with the data of higher frequency, i.e. monthly and daily figures. While annual data are also used in some cases.

Ship size

The second is dealing with ship size. Because deadweight of vessels of three main types keeps increasing, the size categories have been changing over time. For instance, a Capesize vessel is traditionally defined as that over 80,000 dwt before 2000. However, with more and more super-Panamax between 82,000 dwt to 85,000 dwt able to transit the Panamax canal being built, currently, the ship size of Capesize has been increased to be over 100,000 dwt.

In the 1980s and the early 1990s, the standard Panamax design was that of approximately 60,000dwt to 65,000 dwt, with only a few ships larger than 72,000 dwt. With more and more Panamax vessels larger than 72,000 dwt built in late 1990s and those larger than 80,000 dwt built in the early 2000s, a Panamax vessel has been classified as that between 60,000 dwt to 100,000 dwt in this thesis.

With regards to Handymax vessels, there also exists a trend of expanding these ships. In the past decade since 2000, there has been a special type vessel built between 53,000 to 60,000 dwt, with the beam of a Panamax (32.26m) and the length of a traditional Handymax vessel (180-190m). Though it has the same beam of a Panamax, its operational performance is similar as a traditional Handymax. For the marketing purpose, this type of vessel is called Supramax, falling within the Handymax category. Therefore, a Handymax ship refers to that between 35,000 dwt to 60,000 dwt in this thesis. With regards to trading patterns, the smaller Handymax vessels with 35,000-50,000 dwt trade similarly to those of the Handy size segment, while the larger Handymax vessels in excess of 50,000 have almost identical trading patterns with Panamaxes, including the grain seaborne trade within the US Gulf to Japan-China range as well as coal trades. Hence putting them together does not make much sense.

Fleet figures of different ship sizes may be mixed from different sources, or significant discrepancies may be created between the fleet data reported by various sources, especially during the earlier years. For instance, not all class size categories before 1970 were as well developed and well distinguished as today. All of these may affect estimation results. In order to keep data consistency, the fleet data in our thesis are all acquired from Clarkson Intelligent Network (2010).

Because monthly figures can be available from Clarkson Intelligent Network, most often we utilize monthly data of each ship size, for example, monthly one year time charter rates of Capesize with 150,000 dwt. Because the benchmark vessel of each ship size is becoming larger, the time series of a specific ship size is also changing. For instance, figures of one year time charter rate of 125,000 dwt are only available from Jan 1977 to May 2008, because this kind of ship size has not been popular any longer since the late 1990s. Instead, the data of one year time charter rate of 150,000 dwt can be got from Dec 1991 till now. Consequently, we can find that although the dry bulk market analysis in this dissertation starts from 1950, there are never time series of continuous monthly data starting from 1950 or more closer, there are no continuous monthly data of a certain ship size available starting from 1970 till now. So in the following chapters, we only use time series that are still being updating now, though the starting year may be in late 1980s or in early 1990s. For example, time series of one year time charter rates of 150,000 dwt from Jan 1990 to Dec 2010 are used in various models in this thesis, instead of figures of 125,000 dwt. The choices of various time series will be explained in related chapters.

1.3. Outline

This dissertation makes an attempt to provide a unified framework for the economic and econometric research of dry bulk shipping market. As an added objective, the attention is also drawn to the technical aspects of dry bulk ships. Technical innovations over the past decades and ship designs with the optimum technical parameters will be analyzed in an economic way.

The research starts with the discussion of the economic background, including definitions of maritime variables in the dry bulk shipping and the structure of the dry bulk market. From there it defines the scope, objectives and data issues of the dissertation, as such it provides the basis for the whole research and this chapter ends up with the description of the structure of the thesis.

Chapter 2 sets the scene by providing a review on both economic and technological developments in the bulk shipping market over the period from 1950 to 2010. Based on the survey on previous economic evolutions, significant factors influencing these markets and a number of economic relationships are identified. A retrospect of previous market movements can be helpful to understand the economics of the dry bulk shipping industry and lay the solid foundation for further quantitative research. An important part of this chapter is the investigation on the links between the economic performance and technical innovations of dry bulk vessels. The attention has been given to technical changes in the design speed, deadweight, lightweight and the fuel consumption of dry bulk vessels over the last forty years. Triggers for these technical innovations and their impacts on the economic performance are all explained in detail, providing useful information to practitioners of dry bulk shipping in guiding their decisions on the ship building and ship operations.

An extensive review of the quantitative research in the dry bulk shipping is presented in Chapter 3. The investigation on previous modelling work in the bulk shipping industry is mostly on the applications of the advanced time series techniques in the freight market, the new-building market, the second-hand ship market and the freight forward market. These applications concern in particular models of the time varying volatility, the pricing and forecasting of charter rates and ship values. The main purpose of the review of the quantitative analysis is the identification of strengths and weaknesses of various models, which can form the basis of modelling approaches in this thesis.

Chapter 4 presents some investigations on the price behavior in the freight market and the freight derivatives market. At first, time series models are used to investigate dynamic volatilities of charter rates for short and long term charter contracts for three main ship types. Then, the term structure of charter rates is analyzed and the risk premium in the freight market is examined during different market conditions. Additionally, interrelationships between sub sectors in the freight market are checked. Finally, efforts are made for forecasting daily charter rates through the investigation of lead-lag relationships between the spot market and the forward market, and for forecasting monthly charter rates on major trading routes by making use of various time series models. Exogenous variables influencing prices significantly in the freight market are incorporated into some of time series models in order to achieve better forecasting results.

Chapter 5 is devoted to the new-building market. The modelling strategy is applied firstly to the careful investigation into dynamic volatilities of newbuilding ship prices. Relationships between prices in the freight market, the second-hand ship market, the newbuilding ship market and the scrap market are then checked, followed by the prediction of newbuilding prices. Apart from the pricing mechanism in the new-building market, the quality of a new ship is one of the most important concerns of ship-owners. This chapter then provides a new solution to optimizing major design parameters of a new ship for ship-owners within the Monte-Carlo simulation scheme for specific service requirements.

The investigation of the price behavior in the second-hand market is described in Chapter 6. It starts with the modelling of the time-varying variability of second hand ship prices, which is followed by the probe into relations between price variables in the second-hand market, the new-building market, the scrap market and the freight market, the basis for investment and risk management strategies for shipowners. This chapter ends up with the evaluation of the forecasting performance of various models in the prediction of second-hand ship prices.

The main conclusions of all the work in this thesis are summarized in Chapter 7, together with the direction for further research in dry bulk shipping.

Apart from all chapters, the methodological framework of the analysis of dry bulk shipping industry in this thesis is described in Appendix A, including various time series models and economic models. Statistical properties of the data, the model specification, the estimation, checking and forecasting procedures of time series models are all explained extensively, which form the methodology basis for approaches in the whole research.

Chapter 2. A Review of the Dry Bulk Shipping Development

It is widely accepted that the shipping industry is risky by nature. Dry bulk shipping sector, among the shipping industry, has been exposed to many risks, such as financial risks, i.e. risks of financial loss arising from unfavorable changes in freight rates and ship valuations, and transportation risks, i.e. risks of cargo, vessel and crew losses arising from accidents at sea, because it is most competitive and completely non-regulated with international shipping operations and highly complex economic structures. In order to understand better the dry bulk shipping market, we should step back from the current market and review the economic development and technical innovations in the dry bulk market, together with quantitative work done by maritime researchers during the past decades.

For the economic development, we make an analysis of market booms and recessions during the past decades since 1950, aiming for filtering out the essential mechanism and identifying key variables influencing market movements, which will be considered in modelling and forecasting charter rates and/or ship prices in the relevant chapters.

For technical innovations, we investigate the technical changes in dry bulk vessels and examine their impacts on the economic performance of vessels. What is new here is that it's the first time we have made such an in-depth insight into technical changes, including ship speed, deadweight, fuel consumption and lightweight, occurring over the past five decades, and the specific impacts of various technical innovations on the economic performance of ship operation, presenting a good way to examine relationships between technological and economic aspects of ships. This kind of study may therefore contain helpful information for ship-owners to optimize their ship design and/or ship operation.

This chapter consists of two parts. The exposition starts with the introduction and the analysis of economic evolutions over the past five decades. The other section shows changes of technologies applied in the dry bulk vessels built from 1970 to 2008, and examines impacts of technical changes on the economic performance of ships.

2.1 Economic development

This section provides a general introduction of market booms and recessions over the periods from 1950 to 2010 and it presents as well the price volatility over the past decades from the perspective of shipping economics.

2.1.1. A retrospect of the development in the dry bulk market since 1950

The years since 1950 saw a process of expanding trade volumes and great technical changes in the shipping industry. Spurred by the rapid growth of the dry bulk trade, the dry bulk shipping has gained a considerable development since the early 1950s with the invention of dry bulk carriers. Though history rarely repeats itself in detail, there are similarities with recent events. We make a brief retrospect of the past market cycles and list out significant booms and recessions, in order to outline those preceding warning signs ahead of the market collapse by analyzing triggers of peaks and troughs. Consequently, a brief retrospect of its development over the past can be helpful to obtain a clearer picture of its fluctuations and lay the solid foundation for further qualitative research.

- **Period of 1950-1951 boom by the Korea war**

The underlying economic and political environment in the 1950s contributed strongly to a rise in trade and demand for dry cargo shipments, motivating the specialized dry bulk shipping. The first specialized dry bulk vessel was then built in 1950s, followed by the continuous growth of the specialized dry bulk carriers.

The recovery and rapid growth of the economy in European countries and Japan during that period pushed the shipping demand for dry cargoes. In 1951 the Korean War sparked off a stockpiling boom of strategic reserves in the industrialized countries, resulting in a 16 percent growth in the seaborne trade, see Martin Stopford (1997). The spur from the political event easily resulted in rocketing rates. Meanwhile, the bunker prices increased greatly, exerting further pressure on rates. Ship values also experienced a sharp rise supported by the strong freight market. On the supply side, firm prices of the early 1950s led to an expansion in the supply of new-buildings and a reduction in scrapping.

- **Period of 1952-1954 recession by the oversupply**

Unfortunately, the dry bulk market boom only lasted for a year and the demand fell sharply when the Korean crisis ended. Rates and ship prices for dry bulk vessels plummeted due to weak demand and oversupply. By 1953 laid up tonnage had increased considerably. In the first half of 1954, the market still remained depressed, but improved considerably in the second half of this year.

- **Period of 1955-1956 boom by the closure of the Suez Canal**

In the second half of 1954, the market started to recover and the upward trend continued through 1955. When the Suez Canal closed in November 1956, the freight rates of dry bulk vessels rose even above their previous peak during the Korean crisis. Lay-up went to zero and the market witnessed the sky high rates and an ordering jump at the end of 1956. Shipping players were all optimistic about the future market and nobody expected the recession which subsequently happened.

- **Period of 1957-1967 recession by the world economy depression and oversupply**

The Suez prosperity was followed by an unexpectedly severe depression since 1957. The big fall of the world economic growth rate played an important role. The OECD industrial production decreased by 4% in 1958, resulting in a decrease of seaborne trade for the first time since 1950, and the following did not come until 1975. Moreover, in March 1957 the reopening of the Suez Canal cut down the mileage factor in ton-miles. However, the worst was the record delivery of newbuidings during 1958 and 1959, constituted 15% of the existing fleet, at a time of lower demand, primarily responsible for driving rates down. The depression saw ship prices of dry bulk vessels fall by 70% and freight rates by 75% from the peak, with scrapping volumes rising significantly and lay up going up to 7% of the existing fleet, see Beenstock and Vergottis (1993).

With the demand growing greatly, the dry bulk market began to recover in 1963, by which lay-up had fallen to 2% of the existing fleet, see Beenstock and Vergottis (1993). Prices and shipbuilding responded positively and the scrapping fell. Though the market has improved since 1963, the negative shock of the expanded flow of new ships on the dry bulk ship market did not completely eliminate until 1967.

- **Period of 1967-1974 boom by the closure of the Suez Canal and the strong economy**

The long depression was followed by the subsequent more prosperous periods. In the summer of 1967, the closure of the Suez Canal due to the war of Israel and Egypt, marked the start of the market booms. The tanker market benefited directly from such closure, for oil at this time was the main cargo going through the Suez Canal. With the increased demand from the tanker market, most combined carriers were absorbed by the oil shipping, putting the noticeable impact on the dry cargo market. The closure of the Canal from 1967 to 1975 and fundamentally the considerable growth of seaborne trade all contributed a lot to the buoyant market.

On the supply side, the ordering of dry bulk carriers in the past years kept at a relatively low level. The dry cargo deliveries had been on a downward trend as well and it continued up to 1975, in spite of the strong market. The serious imbalance between supply and demand finally resulted in the continuing prosperity.

The prosperity occurring at the end of 1960s lasted till the early 1970s. Regardless of the short-lived recession in 1971, the seaborne trade grew significantly and rose to the record level in 1974, from 1165 million tons in 1970 to 1472 million tons in 1974, the real cause for the prosperous years before 1975. The booms of 1970 and 1973 coincided with the exceptional peaks in the seaborne trade with a 13% and a 13% growth in 1970 and 1973, respectively, see UNCTAD various. In the meantime, the dry cargo market benefited indirectly from the improved rates of ore carriers and of combined vessels switching into the oil trading due to booms in the tanker market. Dry bulk ship values gained a considerable growth during this period with a sharp fall in the laid up tonnage and scrapping. However, deliveries kept on the decrease till 1975, arising from the fact that most shipbuilding capacity has been occupied by the construction of new tankers since the market boomed. In fact, between 1971 and 1976, the tanker construction absorbed 52% of the actual shipbuilding capacity, see Beenstock and Vergottis(1993).

- **Period of 1975-1978 recession by the first oil crisis**

Unfortunately, the tanker market was heavily shocked by the oil crisis, starting on October 17, 1973, as a result of the ongoing Yom Kippur War. As oil price quadrupled, the economic boom was suddenly over. A devastating drop in freight rates and ship values of tankers came after the massive 1973 orders and the stagnation of demand. The stagnation of the tanker demand was important for explaining the subsequent dry cargo depression.

The dry cargo market still held up through 1974, supported by the solid growth in demand and the phenomenal increase in bunker prices. However, with the much depressed tanker market, affected by the oil crisis, the dry cargo market soon became weak. The demand in the dry bulk market decreased in 1975 and remained depressed until 1978. Some tankers ordered in 1973 were converted into bulk carriers thus increasing the supply.

- **Period of 1979-1982 boom by the sound economic growth and limited tonnage supply**

The dry bulk demand was growing faster than the fleet and absorbed a significant amount of surplus capacity between 1978 and 1980. In 1979 the dry bulk market made a partial recovery. Trade in the major bulk commodities grew by 7.5% in 1979, but supply increased by only 2.5% due to the low ordering during the previous recession. On top of this came the knock of the 1979 oil price increase. Power utilities around the world switched from oil to coal, giving a major boost to the thermal coal trade. This effect was reinforced by congestion. Port congestions were widespread in USA but particularly in the Middle East and West Africa where traditional port facilities could not cope with the flood of trade. Cases of ships waiting at the roads of the port of Lagos in Nigeria or in Indian ports were not uncommon at that time.

Due to the exceptionally firm freight market, dry bulk new ships were needed to satisfy the expected growth in demand. Ship values rose to a new post-war high and the orderbook expanded. Time charter rates more than trebled. The dry bulk freight boom continued till 1981, followed by the new high levels of ship values and the orderbook. This short-lived boom was, however, followed by a new depression which was even more severe than the previous one.

- **Period of 1983-1986 recession by the second oil crisis**

The second oil crisis started a new round of severe recession in the world economy, causing the slump in the shipping demand, coming on top of the continuing tanker market depression. The world seaborne trade of dry cargoes dropped for two consecutive years of 1982 and 1983, just 1793 million tons and 1770 million tons, respectively, compared with 1866 million tons in 1981, see the Review of Maritime Transport, 1985.

Despite the depressed freight rates in 1983-1984, large numbers of orders were placed for dry bulk carriers. The whole process was initiated by Sanko steamship, a Japanese Shipping company, which secretly placed orders for 120 ships as it took its last chance to save itself from its creditors. Their example however was soon followed by a flood of orders from international shipowners particularly Greeks and Norwegians, see Martin Stanford (1997). The large cash reserves accumulated during freight booms, the cheap ship prices due to overcapacity of shipyard, the fuel effective new bulk carriers, and the expectation for the upcoming market boom in the next years, can all be responsible for the counter-cyclical ordering.

In 1984, there was a considerable increase in the world seaborne trade, 6.55% up on year-to-year basis. However, heavy deliveries of dry bulk carrier newbuildings and the little employment of combined vessels used in the depressed tanker market, resulted in the limited rise of rates of dry bulk shipping. Though the seaborne trade grew up after 1984, the dry bulk market was still hit by huge deliveries. The freight rates still remained at very low levels. Clarkson research company statistics showed that one year timecharter rate for a Panamax was only about $5485/day in 1985. And the freight rate dropped to $4719/day in 1986. Many shipowners who had borrowed heavily to invest in newbuildings now faced acute financial problems. Ship values of dry bulk vessels also collapsed during 1985-1986.

- **Period of 1987-1995 boom by the strong world economy and limited tonnage supply**

As trade started to grow and scrapping increased, the dry bulk market staged a strong comeback in 1987 and freight rates reached a peak in 1989-1990. One year timecharter rate for a Panamax increased from $4,719/day in 1986 to $13,115/day in 1989. The five-year old Panamax, sold for $6 million in 1986, was worth $12.8 million in 1987, $17.2 million in 1988 and $23 million in 1989, see Clarkson Database.

Dry bulk freight rates peaked along with tankers from 1989 to 1991, but over the years 1988 to 1991 just a few bulk carriers were ordered and delivered, see Figure 2.1.Therefore, when the world economy moved into recession in 1992, the dry bulk market had not much burden from the tonnage supply and after a brief dip dry bulk freight rates recovered, reaching a new peak in 1995. These years of relatively firm market had triggered heavy investment in dry bulk carriers leading to a huge orderbook, which went up to the peak in 1996, see also in Figure 2.1.

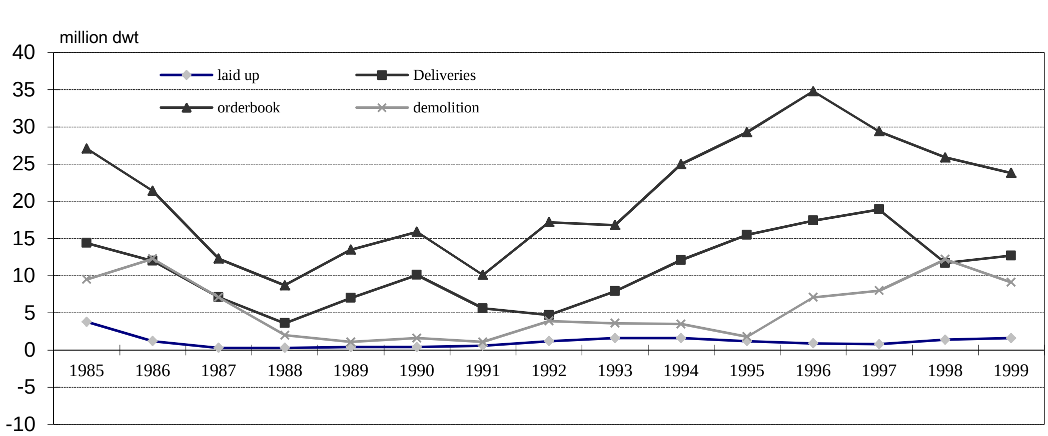

Figure 2.1: Trends of orderbook, delivery, laid up and demolition of dry bulkers

- **Period of 1996-1999 recession by the Asian crisis and short-lived boom in 2000**

As deliveries were continuously up, the dry bulk market moved into recession in 1996. However, the worst was still to come. Beginning in the middle of 1997, many East Asian economies including Indonesia, Korea, Malaysia and Thailand experienced a common set of economic events known collectively as the East Asian crisis. The macroeconomic phenomena that characterized this crisis were a devaluation of the currency exchange rate with the US dollar, a sharp expansion in the current account and a general contraction in the economic production. Dictated by the International Monetary Fund (IMF), contractionary fiscal and monetary policies combined with misguided financial policies led to massive economic downturns, cutting incomes, which reduced imports and led to huge trade surpluses, giving the countries the resources to pay back foreign creditors, see Stiglitz (2002). The world GDP growth was substantially influenced by the Asian financial crisis.

All these had a devastating effect on the bulk carrier market. Lack of demand led to a drop in commodity prices and subsequently in freight rates. Also, the large number of ships, particularly dry bulk carriers that were ordered in the booming years of 1995 and 1996 at high prices were delivered, see also Figure 2.1, thus creating an oversupply of dry bulk ships that led to a substantial drop in dry bulk ship prices. The situation was worsened by the fact that South Korea increased its shipbuilding capacity substantially and, in order to fill it, it offered newbuilding prices that were much lower than any other countries. The Korean shipyard competitiveness was further strengthened thanks to the devaluation of the Korean Won against the dollar. As a result Koreans were able to quote prices for building ships that were higher in Korean won terms but lower in US dollar terms. Shipbuilding prices came under more pressure and many shipyards in other countries were forced out of business.

Bulk carriers started recovering first, along with improvements in the world economy from late 1999 till early 2000. For dry bulk carriers, a low orderbook and an increase in trading further tightening the supply-demand balance, led to the best freight market for the past years.

- **Period of 2001-2002 recession by the IT bubble crisis**

However, the worldwide economic recession came in 2001 when GDP growth declined in many economic communities, the bubble of the IT industry burst and the World Trade Center was attacked on September 11 2001, so the dry bulk market plummeted until the end of 2002. During the year 2001 the growth of world output fell to 1.3 % from the remarkable 3.8 % achieved in 2000. For the first time since the oil price hike of the late 1970s, all regions of the world experienced a simultaneous economic slowdown in 2001 and the dry bulk shipping market was shocked by the economic recession and suffered from huge deliveries. One year timecharter rates for all types of dry bulk vessels dropped and remained at low levels till the end of 2002. Ship values also fell in 2001.

- **Period of 2003-2008 unprecedented boom by the strong world economy**

Fortunately from 2002, the world economy recovered and continued to grow rapidly and strongly till 2007. Stimulated by the sound growth of the world economy, the world seaborne trade gained the consecutive annual increase, especially for the shipments of main bulk commodities, seeing 7.86% annual growth on average from 2003 to 2006. The freight rates of the dry bulk market were soon pushed up by the firm demand. One year timecharter rate for a Panamax soared from an average of $7,499/day in 2001 to a historical peak in 2004. Afterwards it fluctuated in the next two years and rocketed again to a new record high of $71,500 per day in 2007.

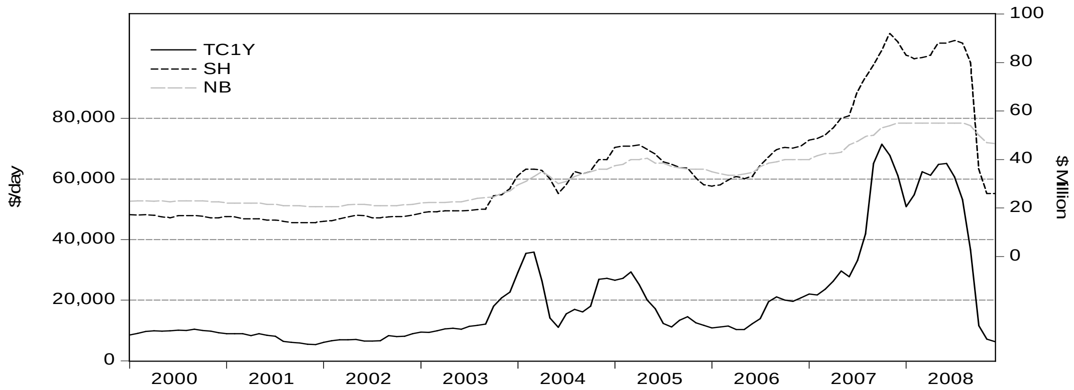

Figure 2.2: One year time-charter rates(TC1Y), 5 year-old second-hand ship prices(SH) and newbuilding prices(NB) for Panamax vessels during 2000-2008

The five-year old Panamax, which was sold for an average of $15 million in 2001, was worth $66.8 million on average in 2007. The average price for a Panamax new vessel in 2007 reached $47 million, over double the value in 2001. This round of the strongly upward trend in ship values can be also shown in Figure 2.2. The buoyant freight market brought about a rocketing increase of orderbook, achieving 100.7 million dwt in 2007 from 33.5 million dwt in 2000. Laid up tonnage was kept at very low level of 0.3-0.4 million dwt per year and demolition reduced abruptly to the record low level of 0.41 million dwt in 2007. The tremendous construction of new-buildings since 2002 also gave rise to large deliveries from 2004.

The reasons for this round of boom since 2002 are many, among which, the robust demand played a significant role. The average growth of the world GDP kept nearly 5% during 2003 to 2007. The strong and sustainable growth of China, India and other dynamic developing countries was increasingly becoming the main driver of the world economy, see Figure 2.3. China’s GDP growth increased by 9.1% in 2002, remained above 10% from 2003 and gained a record high of 11.5% in 2007, see China’s Statistics Bureau. The robust growth of these dynamic countries resulted in an increasing demand for steel since 2002 and triggered a sizeable demand for the dry bulk shipping market. The booming production of steel was reflected in the 5.1% increase in iron ore shipments during 2002. In 2007, it achieved a record level of 789 million tons and about two-thirds of the world imports of iron ore went to China and Japan. China’s imports in 2007 accounted for almost half of the world total, see Figure 2.4.

The soaring freight rates since 2002 were reinforced by port congestions in world’s major bulk terminals, especially in Australia, Brazil and China. The increasing demand for raw materials from China, the world's fastest-growing major economy and the world's biggest consumer of iron ore and coal, contributed to port congestions in Australia as terminals became unable to handle the volume of goods sold for export. The queue of ships waiting to load at Newcastle, Australia, the world's largest coal export terminal, rose by about 3 to 74 in 2007, see Newcastle Port Corporation. Ships waited for about 20 days to discharge cargoes at Qingdao Port, China’s biggest iron ore terminal, in June 2006. Port congestions can soak up a sizeable capacity of vessels, worsening the imbalance between supply and demand. On the other hand, a decline in the cost of shipping coal, iron ore and other dry-bulk goods may be curtailed by the heavy congestions at main terminals.

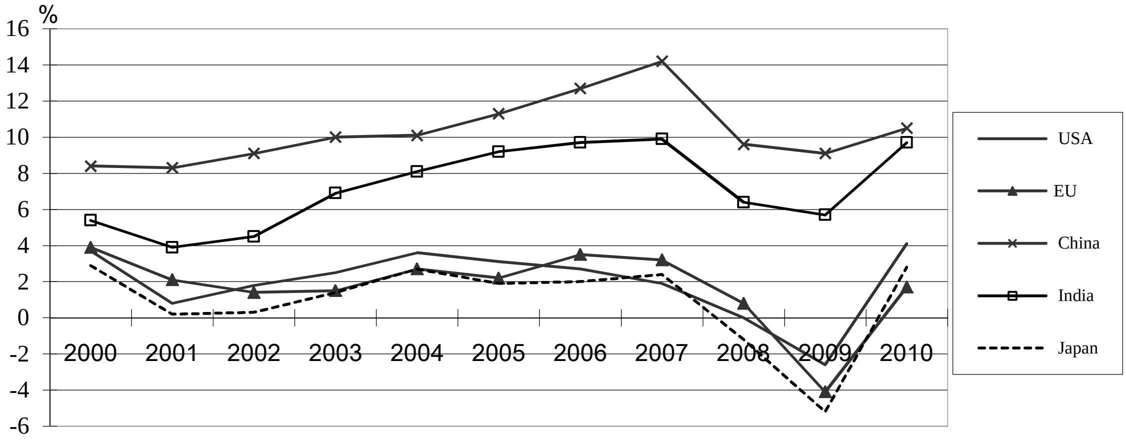

Figure 2.3: Annual growth rate of GDP in different countries and economic communities

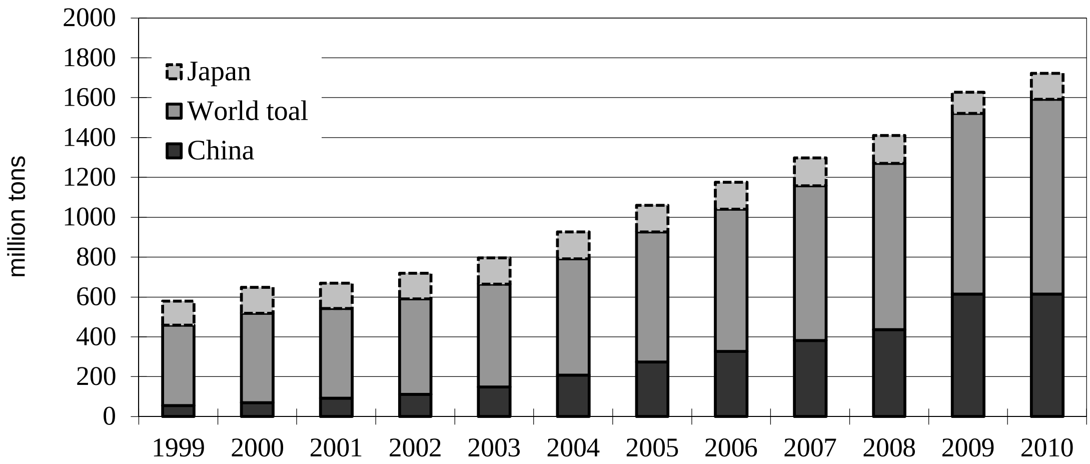

Figure 2.4: Iron ore imports of the world, Japan and China

- **Period of 2009-2010 recession by the credit crisis and oversupply**

It's undoubted that the dry bulk shipping market has gone into recession since the outbreak of the world credit crisis starting in late 2007, which had a devastating and serious impact on the economy and finally dragged down the world economy into recession.

It is known that the majority of the dry bulk shipping demand is considerably stimulated by large amounts of raw materials imports into China since the year of 2004, and it is indeed a worry with so much of the shipping industry connected to the China's steel production. The recession in the US, Europe and Japan starting in late 2008 spilled over into Asia and the economy of China significantly slowed down. The steel production in 2010 was much slowed in the wake of globally gloomy economy and a lack of demand for steel.

In the supply side, ship owners have ordered massive tonnage during the shipping boom since 2004, and the dry bulk shipping market in 2009 and 2010 were heavily hit by the influx of massive fleet capacity growth and heavy deliveries, see Figure 2.5. The total dry bulk fleet in 2010 was 528.8 million dwt, almost double the figure in 2000. Unless there are considerable cancellations and delays for orders, the next couple of years will face a huge challenge from tremendous deliveries and probably lengthen the depressed time in the dry bulk market.

Resulting from the sluggish demand and the surplus of tonnage, charter rates of dry bulk vessels plummeted and so did the ship values of both second-hand and newbuilding vessels after the financial crisis. For example, one year timecharter rate for a Panamax dropped from a record high level of $71,500 per day in 2007 to an average of $15,383 per day in 2010. The five-year old Panamax was worth $38.5 million on average in 2010, down by about 45% compared with the record level in 2007. The average price for a Panamax newbuilding of 75,000-77,000 dwt decreased to $34 million from an average of $53 million in 2008. Fluctuations of one-year time charter rates, second-hand ship prices and newbuilding prices during the past decades can be seen in Figure 2.6.

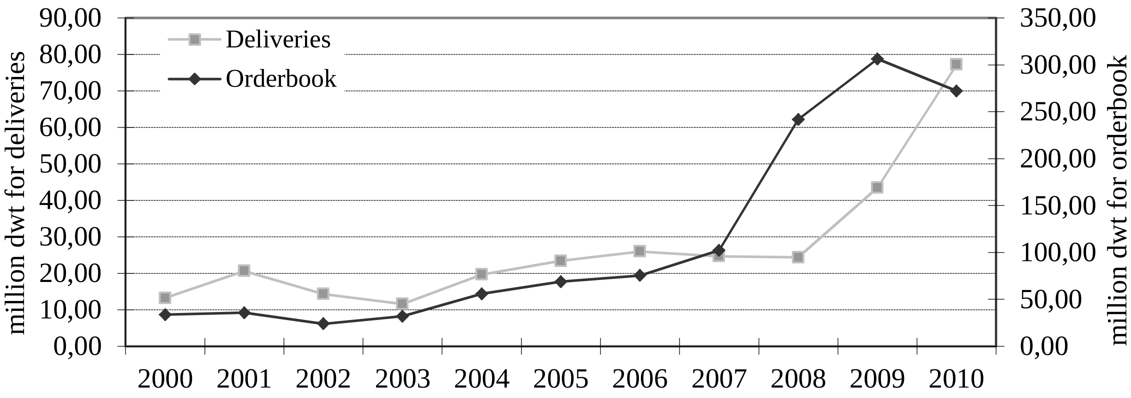

Figure 2.5: Trends of orderbook and deliveries of dry bulk vessels during 2000 to 2010

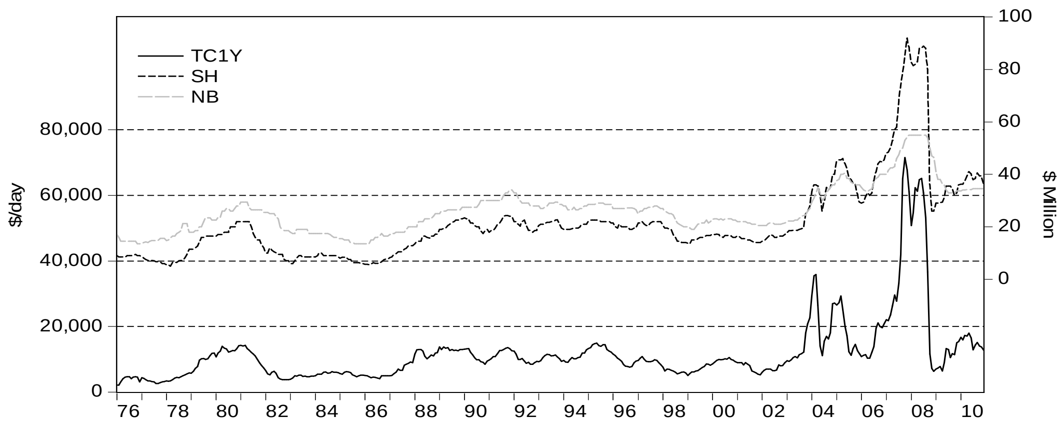

Figure 2.6: One year time-charter rates(TC1Y), 5 year-old second-hand ship prices(SH) and newbuilding prices (NB) for Panamax vessels during 1976-2010

- **The price volatility over the previous decades**

An overview of the evolution in the dry bulk market has been described above. Long period troughs and short peaks dominate the history of shipping cycles. The underlying triggers in each recession or each boom not only cause changes in the price level, but also in the price volatility. If we check the price fluctuations over the past decades, there are discernable differences of price volatilities during different periods. Let's take the volatility of one-year time charter rates for a 65,000 dwt Panamax during the period Jan 1976 to Dec 2010 as an example, see Figure 2.7. It is clearly revealed that compared to the period before 2003, the Panamax market has become much more volatile since 2003. We can find as well that the price volatility is higher over the period hit by the Oil crisis or the financial crisis, and it is always higher during periods switching from the market boom to the market recession or from the market recession to the market boom.

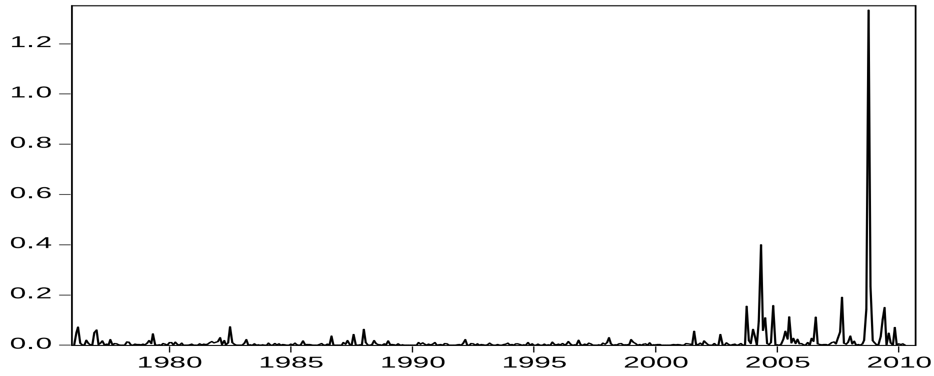

Figure 2.7: The price volatility of one-year time charter rates for Panamax during 1976 to 2010

2.1.2. Learn from the past

History is replete with examples of strong connections between global economic health, the financial stability, the oil price, global unrest and the fortunes of the shipping industry. It is instructive to filter out the underlying important influences through previous shifts and trends in the dry bulk market.

- **The world economy and the derivative seaborne trade**

The world economy is undoubtedly the most important dominant for the demand of dry bulk shipping. It's repeatedly proved by cases of previous recessions and booms. The world economy generates most of the demand for shipping, of which a big part is the demand for dry bulk shipping through imports of raw materials. The up-to-date knowledge of the economic development is crucial in judging the trends of the dry bulk shipping market. The relationship between the world economy and the seaborne trade of dry bulk cargoes is, however, not simple, the investigation needs to be made in order to analyze how the seaborne trade of dry bulk cargoes is influenced by the world economy.

The economic cycles play the most important part in the shipping cycles, so it's very helpful to observe the clear evidence from economic statistics of the recovery, the boom and the recession. However, the principal indicators as the economic growth and the seaborne trade, are normally reported after considerable time lags. The better way is to focus on other preceding signs which can move up prior to a recovery and move down in advance of a recession, and can also be available and updated without any time lag. These indicators include but are not limited to:

- Commodities' prices
- Interest rates
- Exchange rates
- Gold prices
- Industrial stockpiles and orders
- Unemployment rates
- Psychology

These indicators provide the advance warning of turning points in the economy. Such information is useful for the analysis of short-term market trends, and some of these economic indicators will be considered in the modelling and forecasting of prices in the dry bulk market.

- **Political shocks**

The political events pose major impacts on the shipping industry, such as wars, revolutions, conflicts, and strikes. Major political shocks since 1950 are briefly demonstrated in Table 2.1.

Such occurrences do not necessarily bring about the direct influence on the shipping demand, but their indirect consequences are usually considerable, for they will bring about an unexpected up or down in demand due to the soaring stockpiles or economy recessions, as well as an increase in shipping costs due to higher bunker prices resulting from oil shocks caused by political shocks in the OPEC countries.

The Korea War in the early 1950s sparked off a booming stockpiling in the industrial countries, directly boosting the dry bulk shipping demand. The Suez Crises in 1956 and in 1967 created longer hauls for large bulk carriers, a sudden increase in shipping demand. Two oil shocks in 1973 due to the Yom Kippur War and in 1979 due to the Iran revolution triggered the subsequent lean years of the world economy. The Iraqi invasion of Kuwait in the summer of 1990 triggered the spike in the price of oil, partly responsible for the global recession in the early 1990s. Similarly, the tensions in the Middle East in 2000 made oil prices rocket, the important trigger of the global recession in 2001. The civil unrest in Venezuela in 2002, the Iraq war since 2003, and the conflicts in the Middle East all lead to a reduction in the oil supply, an additional surge in prices.

Additionally, high bunker prices due to oil crises made new ships designed to consume less fuel oil. We can see quite a few efficient new dry bulk ships built in 1980s.

Table 2.1: Major political shocks since 1950

Date	**Political Event**
1951	Korea War
November 1957	Suez Crisis
August 1967	Suez Crisis/Israel and Egypt War
October 1973	Yom-Kippur War
October 1978	Iranian Revolution
September 1980	Iran-Iraq War
August 1990	Persian Gulf War
December 2002	Civil Unrest in Venezuela
March 2003	Iraq War

- **Ordering, deliveries and scrapping**

The shipping market is shocked by a direct influence from the supply side, including deliveries and scrapping. A decline in freight rates is more likely to be brought about by the excessive supply than the falling demand. The severe shipping troughs in the past were all accelerated by oversupply caused by heavy deliveries during hard times. Quite a few tankers were converted into bulk carriers due to the collapsed tanker market in 1973, increasing the supply of the dry bulk sector and worsening the market during the recession of 1975 to 1978. A large number of bulk carriers were ordered in the depressed years of 1983-1984, resulting in heavy deliveries in the subsequent two years. Thus the dry bulk market was still hit by huge deliveries though there was a considerable increase in the seaborne trade growth after 1984, and freight rates and ship values collapsed during the period of 1985 to 1986. Oversupply was also witnessed in other shipping troughs. The unexpected shipping boom since 2004 has brought consecutively massive orders and deliveries, which dampened already weak market after the financial crisis in 2008.

- **Market sentiment coupled with the price volatility**

Market sentiment in the shipping community can be described as the intuitive feeling or tone of the shipping market (i.e. crowd psychology), running as a great factor influencing the price fluctuations. Hampton M.J. (1990) stressed the importance of psychology in the shipping market, who pointed out that in any market including the shipping market, participants were caught up in a struggle between fear and greed. The psychology of the crowd fed upon itself until it reached an extreme that cannot be sustained. Once the extreme was reached, too many decisions had been made out of emotion.

The crowd psychology can be shown by changes in the price level and the price volatility. Many important turning points in the shipping market are associated with psychological extremes. When the booming market comes, it witnesses the recorded freight rates, expensive ship values, crazy orderings and low levels of laid up and demolition as well as a strong feeling of optimism or a willingness to take speculative chances, examples are years of 2004-2005, 2007 and the first half of 2008 among others. And the principle applies to the reverse situation as well. Examples are years of 2009 and 2010 among others. If the market sentiment is bearish, freight rates suffer lower levels, investors are reluctant to put money any more and the ship values are greatly squeezed. There must be some excesses when very fancy prices are paid for old vessels or very fancy vessels are paid very poor prices.

The principles of the market psychology underlie each shipping cycle and trigger the large volatility, a good understanding of market sentiment theory and its application, therefore, is crucial to the better understanding of price changes. Successful investors appear to have an intuitive grasp of the crow psychology, who can earn money by searching carefully among unpopular investments.

- **Technological innovations**

Besides the expanded seaborne trade, the past decades since 1950 also saw the process of radical technological innovations, and some significant technical improvements in dry bulk vessels are depicted in Table 2.2.

These technical innovations were primarily triggered by some economic, ship safety and environmental considerations, and they would finally have an impact on various shipping costs. For instance, the improved hull structure and the use of the high-tensile steel can reduce the lightweight and cut building costs. The improved engine technologies can allow vessels to burn heavy fuels and consume less fuel. The self-loading and discharging equipment in the dry bulk vessels can increase the flexibility of cargo handling, which will finally save money.

These technical innovations have taken place gradually over the past decades. Slight changes in technologies may be noticed over a short period, but if we check innovations over a long period, we may find substantial changes. Some of the technical changes would bring about a considerable long-term impact on the reduction of shipping costs, including the capital cost, operating costs (manning costs, stores and lubricants, repairs and maintenance, insurance, as well as administration) and voyage costs (bunkers, port disbursements and canal toll, if any). The in-depth relationships between technical innovations and the economic performance of dry bulk vessels during the previous decades will be analyzed in Section 2.2.

Table 2.2: Examples of technical innovations applied in dry bulk vessels over the past decades

Years	*Technical Innovations*	*Triggers/reasons*
1950s	Dry bulk carriers were built exclusively for the carriage of cargoes in bulk	The increasing demand for shipping bulk cargoes
The end of 1950s and 1960s	Combined bulk carriers were built, including the OBO, carrying a combination of oil, bulk and ore and O/O carrying oil and ore	To increase the operational flexibility
1970s	Satellite navigation, the unmanned engine room and the monitored service system	A result of the computerized automation and technology
1970s	Dry bulk vessels become bigger in size and carrying capacity. Vessels over 200,000 dwt were operating in 1970s.	The economies of scale
The late 1970s and early 1980s	Experimental designs using coal to fuel ships were tested	A result of the 1973 oil crisis and the 1979 energy crisis
The early 1980s	High-tensile steel was used increasingly in the construction of bulk carriers	To reduce the lightweight and cut building costs
The early 1990s	Computerized cargo loading & unloading control system and the global position system; New vessel propulsion technology based on the low fuel consumption and the low maintenance diesel engines	Improvements in the computerized technology and the engine technology
The late 1990s and early 2000s	The double-sided bulk carrier designed and built	To improve the ship safety
The late 2000s and early 2010s	New green bulk carriers designed and built	To make shipping more environmental friendly

2.2 Technical innovations[1]

The period since 1950 can be characterized by the expanding trade volumes and great technical changes in the shipping industry. The continued expansion of world seaborne trade has provided a growing market for the products of advanced ship technologies. The world seaborne trade increased from 1674 million tons in 1965 to 8428 million tons in 2010, see UNCTAD (1970-2010). Such tremendous growth provided the impetus to the accelerating changes in ship technologies. Spencer (2004) concludes that significant technical innovations applied in the vessels have been achieved in the past, including new propulsion technology, low maintenance diesel engines able to burn cheap fuels, automated propulsion and navigation systems, unmanned engine room, and revolutionary structural designs aimed at improving ship safety and lessening the risk to the crew and environment.

Triggers for technical innovations were already examined earlier by researchers, one example of

[1] Section 2.2 is based on the paper ‘Technical changes and impacts on economic performance of dry bulk vessels’, published on the *Journal of Maritime Policy and Management*

which is Wijnolst et al (1993). He recognizes five triggers: the physical laws trigger, the geographical conditions trigger, the economic parameters trigger, the international regulations trigger and triggers of technological changes in the related sectors. Amongst the triggers mentioned above, the economical advantage is an important one if not the most important trigger for technical innovations. So this section will explain technical innovations from an economic point of view and describe the relationship between the innovations and the influence on shipping costs or revenues for dry bulk vessels. The innovation as such, for example, is not a decrease of the fuel consumption but an improvement in engine design and/or an improvement in hull design. Research questions to be answered include: what technical changes have happened in the past? What brought about these changes? What impacts have these changes had on the economic performance of vessels?

In order to investigate technical changes of dry bulk vessels, a ship database and a voyage database have been constructed. The ship database contains the main particulars of dry bulk vessels built during the period of 1970 to 2008, including length over all (L_{oa}), length between perpendiculars (L_{bp}), width, draft, moulded depth, gross tonnage, grain capacity, lightweight, total displacement, maximum deadweight, design speed, fuel consumption, installed horsepower, and engine type, collected from Clarkson intelligent network (2008), Lloyd's ship register (2008), RINA (1990-2006) and Chinica shipbrokers company. By compensating for the differences in length, displacement and other main dimensions, benchmarks for the hull performance, the chosen speed and lightweight are developed, which enable us to use all the vessels in one database instead of studying each bulk carrier type separately. This is confirmed by the fact that three main types display roughly the same trends in the researched parameters in their own class.

Additionally, the voyage database comprises voyage information necessary in calculating voyage costs and freight rates for the carriage of soybean from the US Gulf to North China, by the standard Panamax bulk carrier. All figures in this database are updated in May 2008 and collected from Chinica shipbroker's company.

The rest of this section is organized as follows. A general picture of what kind of technical changes triggered by economic considerations will be presented at first, followed by an in-depth investigation into the technical changes and their influence on the costs and benefits of operating dry bulk vessels.

2.2.1. Economic triggers for technical innovations

Ship-owners are mostly interested in economical advantages resulting from technical innovations. Decisions with respect to new or improved technologies used in new buildings have to be based on economic grounds. Ship-owners always prefer vessels which can either minimize costs or maximize the earnings potential. Hughes (1996) proposes that since ship owners consider most of the transport costs as constant, the margin is determined by how much revenue can be earned with the ship and this is called the 'earnings potential' in shipping. Veenstra and Ludema (2006) address further that the earnings potential consists of three main items relevant to technical variables: cargo carrying volume, speed and ship's flexibility in picking up different cargoes. Consequently, changes in main technical variables are not only motivated to lower costs, but also to acquire a high earnings potential.

Earnings potential for a given ship can be estimated by revenue calculations, extensively described in Stopford (2002). Figure 2.8 depicts all elements in revenue calculations, under a voyage charter contract[2] and we would like to know basically what technical changes are triggered by these elements.

2 The costs of transport are divided based on types of chartering, including bareboat charter, timecharter and voyage harter. Shipowners need to pay for the capital costs under bareboat charter contracts, the capital and operational costs under timecharter contracts, and the total costs except loading and discharging charges negotiated between two parties.

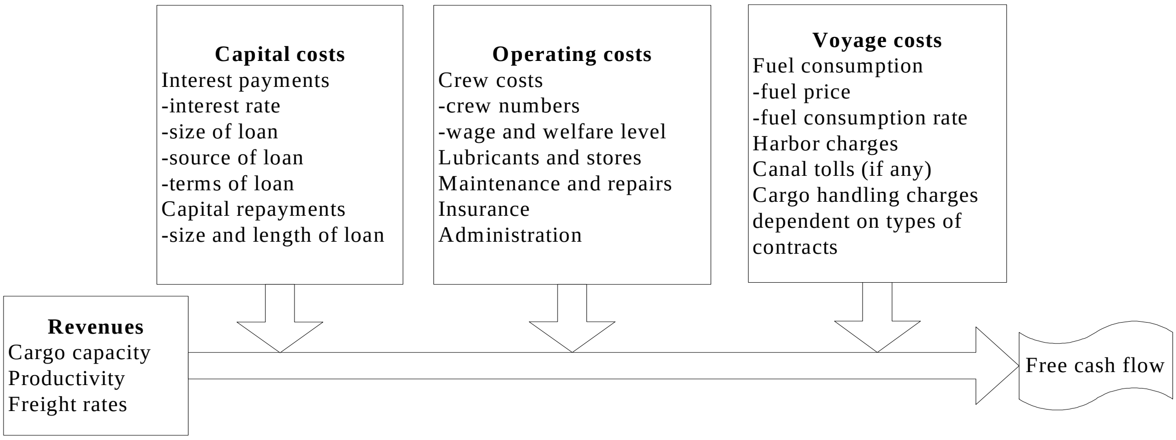

Figure 2.8: Revenue and cost variables
Source: Stopford (2002)

Revenues are received from trading the vessel. There are various ways of squeezing more revenues out of a ship, mainly influenced by cargo capacity, ship productivity and freight rates. Increasing cargo capacity to achieve economies of scale is one solution with respect to technology.

Apart from revenues, lowering shipping costs is another important aspect that ship owners aim for. It's widely accepted that the total costs for a ship can be categorized into three: capital costs, operating costs and voyage costs.

In general, capital costs depend on the building price and the way the ship has been financed. The building price is associated with building costs, a certain percentage of profit and a shipyard subsidy, if any. While financing costs are varied with the size and terms of loans, interest rates and the length. Since building costs of a ship take up a large portion of the final new-building price, it's necessary for ship-owners to know the components of building costs, so as to see which parts heavily influence the ship price. Generally, building costs can be split up into material costs and labor costs. Material costs cover the costs of purchased materials, systems and outfitting, while labor costs are mainly determined by the required man hours per ton steel and costs per hour, both time dependent. Therefore, building costs are significantly influenced by the light ship weight and power requirement. The lightship weight can be subdivided in the structural weight and the weight for outfitting and machinery, while the required machinery will be influenced by the hull performance.

Operational costs or running costs constitute expenses in crew wages and welfare, stores, lubricants, repair and maintenance, insurance, as well as administration. They are mainly determined by governmental regulations describing the minimum number of crewmembers and the technical necessity to maintain the vessel which in itself will require a certain amount of crew members. Another interesting point in this area is the off-hire time each year, required for docking or maintenance which will directly influence the revenues of the vessel. The reduction of operational costs can be achieved through ship automation by minimizing crews and efficient ship management by cutting down other running costs.

Voyage costs mainly refer to fuel costs, canal tolls, harbour charges and cargo handling costs (loading and discharging charges). The canal costs, cargo handling costs etc. do not strongly influence the overall voyage costs, however, the fuel consumption per ton mile does. The fuel costs depend on the hull performance and the engine performance. The hull performance determines the shaft power required to give a certain speed to the vessel. The engine performance is the efficiency of the main engine.

The above discussion indicates that revenues or shipping costs of a ship have close relations with its technical specifications: ship size, cargo carrying capacity, the design speed, fuel consumption, main/auxiliary engines and propeller installed. Such relationships will be examined specifically in the further parts.

In order to investigate the trends of performance improvements in the design of bulk carriers, it is essential to develop performance indicators. The performance indicators could be limited to the capital costs, mainly defined by the lightship, the operational costs by the crew number, and the voyage costs by the fuel consumption per ton-mile. Since the goal is to investigate the impact of innovation on the cost/revenue levels of bulk carriers, the innovation as such for example is not a decrease of the fuel consumption but an improvement in engine design and/or an improvement in hull design. In other words, there are more technological parameters determining the fuel consumption than one. Some technologies can be stretched more than others due to physical limits which differ per technology. So, going one step deeper in performance indicators and coupling them to the basic process enables us to describe the impact of certain areas of development.

To study the performance of vessels in the past we need a database with enough data to be able to determine the above mentioned performance improvements. Most of the ship data are found at Clarkson intelligent network (2008), and additionally quite a few ships published in the journal of Significant Ships[3] are added into the database. The final database used for this analysis contains 386 vessels, from which the light weight and fuel consumption are known besides the other main dimensions. It consists of 62 Capesize, 196 Panamax, and 128 Handymax vessels. By developing benchmarks for the hull performance, the chosen design speed and the lightweight development which take into account differences in length, displacement and other main dimensions, it is possible to use all the vessels in one database instead of studying each type separately. This is confirmed by the fact that in type studies all the types have the same trends in the researched parameters. Further on, most applied new technology can be applied to all vessels.

Elaborating such relationships has great implications to market participants in the dry bulk shipping. For example, the ship owners can put forward appropriate suggestions about the technical specifications of a new building vessel to attain their economic targets, or can make suitable decisions to enhance the earnings potential when operating a vessel, based on a close insight into the relationship between the technical specifications and the economic performance of a vessel.

This part presents a lengthy survey of technical changes of dry bulk ships, detailed investigation in these changes from economical aspects, and specific analysis of their impacts on the economic performance.

2.2.2. Changes in speed and impacts on economic performance

The design speed of a vessel is of great concern to ship owners, because speed changes have a significant influence on the operational benefits and also an influence on the investment and hydrodynamic shape design. The speed is always considered together with the required engine power for a given ship hull. It is not the higher, the better. Consequently, to optimize the speed/power relationship for a given ship always attracts the attention of researchers.

2.2.2.1. Changes in the design speed

To judge a design speed correctly, a simple comparison in knots does not give a correct picture of the impact of speed on the economics. Therefore, the benchmark for chosen speed is developed by compensating for differences in length, in order to filter out a clear trend in design speed for dry bulk vessels.

---

3 Significant Ships is a yearly produced summary of significant new buildings publicated by the Royal Institution of Naval Architects.

Above a certain speed the power demand of a vessel will increase substantially. The operating speed is normally just before this point. However this point varies with the length of the vessel. The relation between the speed and the length of a vessel can be described by the Froude number, $F_n = V / \sqrt{g \times L}$. Two vessels with the same Froude number with different lengths are at the same relative position on the speed resistance curve and are as a consequence in their economical working point roughly comparable. So, after determining the average Froude number of the vessels in the database the benchmark speed has been determined per ship by multiplying the average Froude number by $\sqrt{g \times L}$. The actual design speed as a percentage of the benchmark speed is shown in Figure 2.9.

It's clearly revealed in Figure 2.9 that the average design speed for vessels built during the period from 1975 to 1980 is comparatively high, while it drops to a lower level during the period from the early 1980s to the early 1990s. Since the mid-1990s, it has the tendency to slightly increase again.

To determine the design speed of a vessel is not only a technical issue, but an economical one. It is related with fuel consumption, building costs and revenues. Given a standardized ship, the design speed of a ship could be increased by enhancing the power of the main engine, but this will bring about more building costs as well as costs for bunkers and lubrication oil. Therefore, it is of great importance for ship owners to determine the optimal design speed of a vessel.

Because the optimal design speed for ship-owners is related with economic calculations based on different service requirements, it's necessary to make clear what factors are involved in the economic performance of a vessel with respect to the speed, so as to explain further the trends of the design speed for dry bulk carriers built during the past decades.

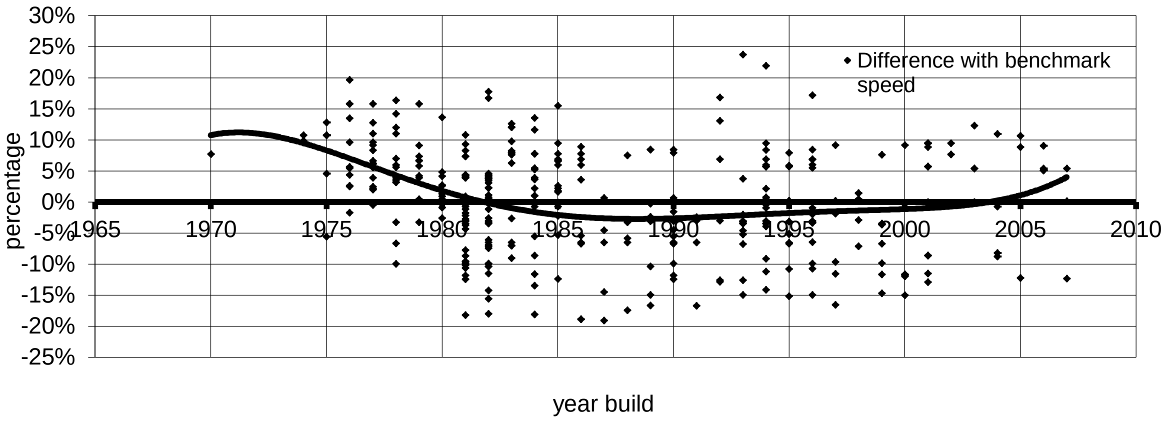

Figure 2.9: The speed trend for dry bulk vessels

2.2.2.2.Economic analysis of the speed

In order to explain concisely the relationship between the technical specifications and the economic performance of a ship, it's assumed that a vessel is used for the carriage of cargoes in consecutive return voyages between port A and port B. Changes in the speed and the relationships between the speed and transport costs, the speed and profits, as well as the speed and bunker prices will be examined from the economic perspective. Such an analysis can create useful information to decisions made not only in building new vessels, but in sales and purchase, as well as operation of vessels.

♦ **The relationship between the speed and transport costs per unit**

Transport costs here cover capital costs, operational and voyage costs. The transport costs per unit of cargo turnover a_t, is used as a performance indicator to investigate the relationship between the speed and the costs. The indicator is expressed simply as

$$a_t = S / Q_{tm} \tag{2.1}$$

Where a_t denotes the transport costs per unit of cargo turnover, S is the transport costs per year, and Q_{tm} implies the cargo turnover per year, ($t \cdot nmile$). Q_{tm} can be written as

$$Q_{tm} = \frac{(\alpha_1 + \alpha_2) DW \cdot T \cdot L}{t_{s1} + t_{s2} + t_{p1} + t_{p2} + t_3} = \frac{(\alpha_1 + \alpha_2) DW \cdot T \cdot L}{\frac{2L}{24V_S} + t_{s2} + \frac{2(\alpha_1 + \alpha_2) DW}{M_c} + t_{p2} + t_3} \tag{2.2}$$

Here α_1 and α_2 represent the utilization ratio of ship's deadweight capacity for inbound and outbound voyages, respectively. T denotes the service days per year, L indicates the voyage distance, M_c is the average cargo handling rate at port.

t_{s1}-sailing time at service speed for a round voyage

t_{s2} -time of canal transit for a round voyage

t_{p1} -cargo loading and discharging time for a round voyage

t_{p2} -turn time for a round voyage

t_3 -extra time at sea and in port for a round voyage

Differentiating Equation (2.2) with respect to V_s gives

$$dQ_{tm} = Q_{tm} \cdot \frac{t_{s1}}{t} \cdot \frac{dV_s}{V_s} \tag{2.3}$$

Then, substituting Equation (2.3) into the differential equation of Expression (2.1), we have

$$da_t = a_t \left(\frac{dS}{S} - \frac{dQ_{tm}}{Q_{tm}}\right) = a_t \left(\frac{dS}{S} - \frac{t_{s1}}{t} \cdot \frac{dV_s}{V_s}\right) \tag{2.4}$$

From Equation (2.4), it's clear that it is economical to increase the design speed when the coefficient t_{s1} / t is large. i.e. the economical advantage takes effect for the vessel with low speed at a long distance voyage. This can partly explain why the average speed of dry bulk vessels has remained relatively low during the past decades.

Furthermore, during the normal operation of a ship, ship owners are concerned about selecting the optimal speed at which the transport costs are lowest. This speed is also known as the economical one. Research on the determination of the optimal speed has been attempted by a number of maritime economists, among which are Ronen (1982) and Buxton (1987). Approaches proposed by these researchers are all based on a total cost function, expressed in terms of the speed. The optimal value is then determined by setting the first derivative of this function to be zero. More details can be found as follows.

Expression (2.1) can also be represented as:

$$a_t = \frac{K_{fixed} + K_{fuel} + K_{others}}{Q_t \cdot 24(V_s + c)} \tag{2.5}$$

Where K_{fixed} is the fixed costs per day, including capital and running costs; K_{fuel} means the bunker costs per day; K_{others} denotes other voyage costs per day; Q_t refers to cargo quantity loaded on board; V_s means service speed and c is the speed change (plus or minus) according to the sea conditions. Clearly,

$$K_{fuel} = P_e \cdot 24g \cdot 10^{-6} C_{fuel} \tag{2.6}$$

$$C_a = \frac{\Delta^{2/3} \cdot V^3}{P_e} \tag{2.7}$$

Where P_e means power (kilowatt); g is the fuel consumption per hour per kilowatt; C_{fuel} is the bunker price (\$/t); C_a represents the admiralty coefficient; and Δ denotes the displacement (ton).

Then, substituting Equation (2.7) into Equation (2.6) results in

$$K_{fuel} = \Delta^{2/3} \cdot 24g \cdot 10^{-6} C_{fuel} / C_a \cdot V_s^3 = kV_s^3 \quad (2.8)$$

Where k is the coefficient relative to the ship engine and the fuel price.

Suppose $c = 0$, the economical speed at which the transport costs per unit are lowest can be determined by setting the first derivative of Function (2.5) to be zero.

$$V_e = \sqrt[3]{\frac{K_{fixed} + K_{others}}{2k}} \quad (2.9)$$

Where V_e denotes the economical speed and k is the coefficient relative to the ship engine and the fuel price.

From Equation (2.9), we know that the economical speed will increase when fixed costs (including capital costs and running costs) are becoming more. Furthermore, it will be increased when bunker costs drop (the reduced specific fuel consumption for the main engine and/or lowered bunker prices will both lead to fewer bunker costs) and vice versa. Impacts of bunker prices on the economical speed can be explained specifically as follows.

Based on the voyage database, the economic speed at different bunker prices can be worked out and illustrated in Figure 2.10. In the database, the Panamax with 73,000 dwt, carrying 58,500 tons of soy bean, operates USG/ North China (Dalian), which is 10,113 miles, at 14 knots burning about 35 tonnes/day at laden and 31 tonnes/day in ballast. When fuel price (IFO) is \$368/tonne, the economical speed for the Panamax should be 14 knots. When fuel price rockets up by 40%, the vessel should slow down to 13 knots to save costs, while when it drops by 24% to \$280/tonne, the optimum speed is increased to 15.5 knots, if technically possible.

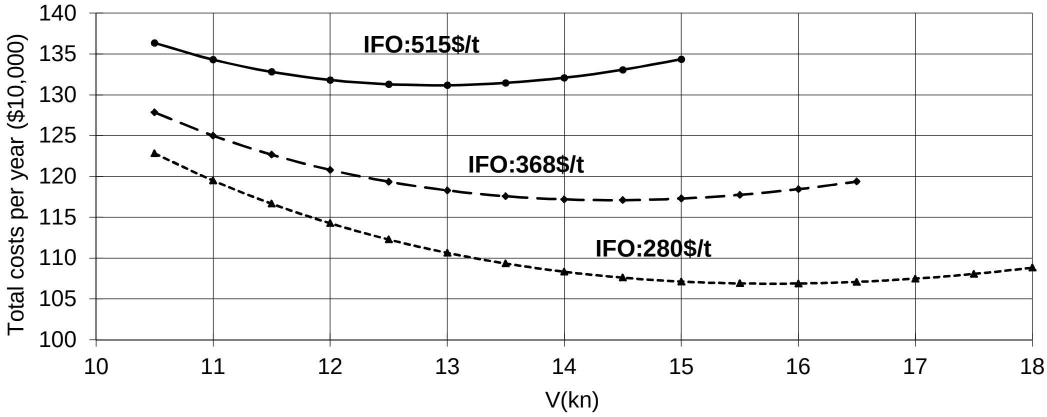

Figure 2.10: The economical speeds at different bunker prices

- **The relationship between the speed and profits per unit**

Apart from the economical speed, ship owners also show much interest at the speed at which the maximum profits can be achieved per day. The maximum profits per day can be represented as

$$r_{\max} = \frac{F - (kV^3 t_s + K_p t_p + K_{others})}{T} \quad (2.10)$$

Where $r_{\max}$ is the maximum profits per day; F means revenues for a particular voyage; K_p represents the costs spent at ports per day; T denotes the service days per year; t_s is the time spent at sea and t_p is equal to $(t_{p1} + t_{p2})$;

The optimal speed is determined by setting the first derivative of Equation (2.10) equal to zero, and we have

$$V_p = \sqrt[3]{\frac{r_{\max} + K_p + K_{others}}{2k}} \tag{2.11}$$

Where V_p denotes the optimum speed at which the maximum profits per day can be earned.

It's shown from Equation (2.11) that the optimal speed V_p is higher than the economical speed V_e under the same costs. In addition, it will be lowered when bunker costs increase and increased when the market price level becomes higher.

The relationship between the optimum speed and freight rates is examined specifically. For example, a Panamax with 73,000 dwt, carrying 58,500 tons of soybean, operates USG/ North China (Dalian), which is 10,113 miles, at 14 knots burning about 35 tonnes/day laden and 31 tonnes/day in ballast. The bunker price for IFO380 remains at \$515/t, and at \$974/t for MDO. The most profitable speed at different freight rates can be illustrated in Figure 2.11. When freight rate remains at \$100/tonne, the most profitable speed for the Panamax should be 14 knots. As the market level goes up, the vessel should speed up to 15 knots to make profits maximum per sailing day, while when the market falls, so does the optimum speed (13.5 knots).

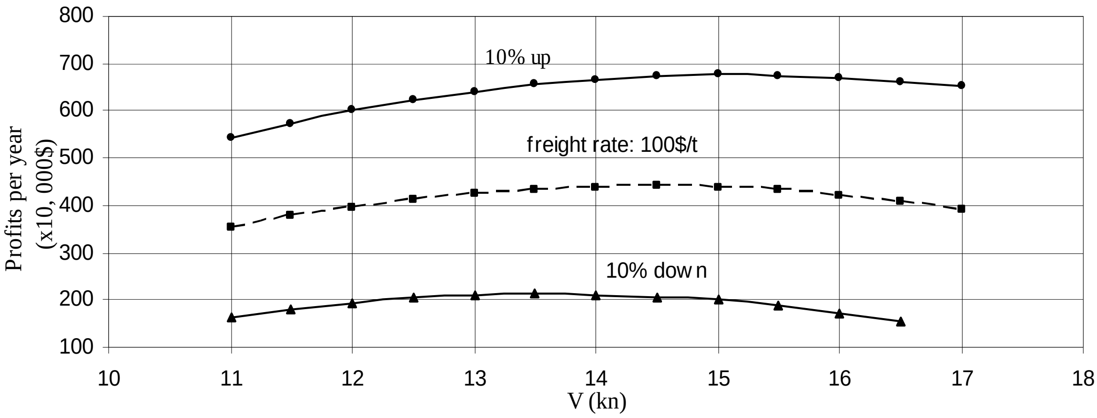

Figure 2.11: The optimal speed at different market levels

♦ **The impact of bunker prices on the optimum speed**

As explained above, bunker cost has a significant impact on the optimum speed and it attracts great attention of ship owners when bunker prices soar to high levels. For most of the last 20 years bunker oil cost next to nothing - between 1988 and 2003, 380cst edged up, with a few spikes, from \$70/tonne to \$152/tonne, a little more than double over 15 years. However, the price doubled to \$300/tonne first in March 2006 and again in May 2007, and it has doubled further again to \$700/tonne by July 2008. That's an extra \$400/tonne within one year. This price escalation affects the profitability of a shipping company.

For example, a Panamax carrier designed to operate at 14 knots burns about 35 tonnes/day at laden and 31 tonnes/day in ballast. Operating USG/North China (Dalian), which is 10,113 miles, and using the "cube rule" (the fuel consumption per unit is approximately proportional to the third power of the speed) to adjust fuel consumption in response to changes in speed, we calculated whether adjusting speed in response to bunker prices is profitable, see Figure 2.12.

With bunkers at \$205/tonne, the lowest line in the graph shows slow steaming does not make sense, unless timecharter rates fall below \$20,000/day. But if the calculation is repeated at \$618/tonne, the three profitability curves, for 12 knots, 13 knots and 13.5 knots, show that at timecharter rates below \$60,000/day slow steaming is profit-able. At $40,000/day, for example, the ship would save over $1,000/day by slowing to 13 knots and almost $2,000/day by slowing to 12 knots. Above $60,000/day it is not profitable to slow down. The curves show that at bunker prices over $600/tonne, even quite small reductions in speed are profitable at freight rates below $60,000/day.

Additionally, slowing down the speed doesn't just save the owners' money, it has another effect. When the speed slows down, the ship delivers less cargo, reducing the tonnage supply, so it has a major effect on the tonnage supply and cushions the fall in earnings when deliveries remain high.

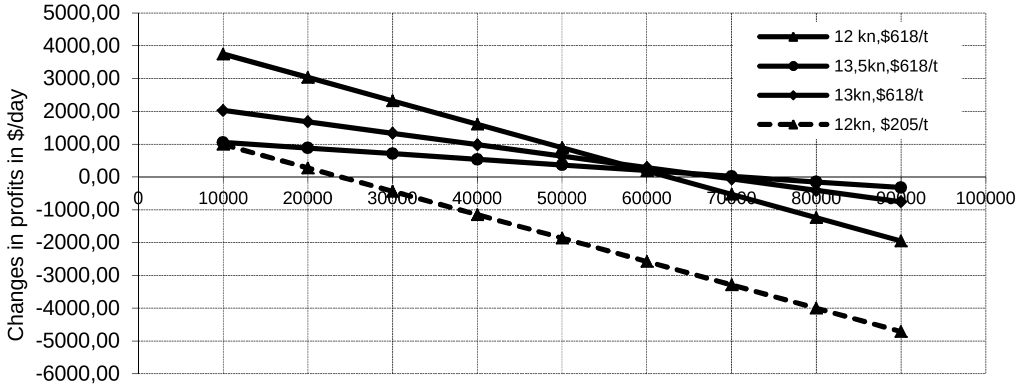

Figure 2.12: Profit changes in response to speed and bunker prices

Through the analysis of the optimum speed in operation, two significant factors probably affecting the optimum speed can be filtered out. One is the bunker costs, and the other is the market price level, which will be considered by ship owners in making a decision about the design speed. For example, the oil crises in 1979/1980 provoked a round of severe recession in the world economy, causing the slump in shipping demand. The high oil prices from the mid of 1979 to 1986, together with lower time charter rates during the period from 1981 to 1986, have, to a large extent, influenced the choices of the design speed of dry bulk vessels ordered during these periods. Many ship owners preferred vessels with low speed, so as to reduce costs during hard times. This can explain why the average design speed built during the early 1980s to the end of the 1980s is relatively lower than that in other periods. Since 2002, the dry bulk shipping market has started a new round of long prosperity, together with continuously rising bunker prices, therefore, on one hand, the average design speed increases slightly to procure more revenues during the booming period, and on the other hand, the increase in the design speed has to be limited by the soaring bunker prices.

2.2.3. Changes in deadweight and impacts on economic performance

Over the past decades, the size of dry bulk carriers has been increased due to reasons of 'economy of scale'. And the trend for vessels to become larger is linked with a specialization of vessels. Both processes have great impacts on maritime transport, examples are port and canal expansion, as well as market specialization. A considerable number of previous studies concerning the ship's carrying capacity focus on the determination of the optimal size, such as Jansson and Shneerson (1982) and Talley and Pope (1988), among others. While here we try to examine the impact of technology on deadweight.

2.2.3.1.Changes in deadweight

- Distribution of bulk carrier fleet by classes

Significant changes can be clearly seen for different types of dry bulk carriers. In numbers, both the Handysize, Handymax and Panamax bulk carriers built today are dominating. Figure 2.13 depicts the distribution of the bulk carrier fleet (larger than 10,000 dwt) in classes. Nearly 70% of the bulk carrier fleet

– in number of ships – is smaller than 60,000 dwt, with the dominating 42% being Handysize vessels. The Panamax vessels account for 22%, and the large ships, Capesize to VLBC, account for about 10% of the fleet. When comparing the total deadweight, instead of the number of ships, the distribution of bulk carrier classes changes in favour of the larger bulk carriers as Panamax and Capesize (see also Figure 2.13). Panamax bulk carriers continue to grow in cargo capacity and the range of the Capesize bulk carriers has been increased as the largest bulk carriers are becoming bigger and bigger.

Such a trend of becoming larger in size can also be illustrated well by changes in each size class (see Figure 2.14). During 1998 to 2008, The development of the Capesize vessel can be seen by looking at the existing fleet distribution through the 'baby Capesizes', with a peak settling within the 160,000-200,000 dwt range, especially for 170,000-180,000 dwt; The preference for this size stems from the need for operational flexibility and is governed by port restrictions in France (Dunkirkmax, limited to a 45 meter beam and 289 meter length), Australia (Newcastlemax, with a 47 meter beam), and Japan (draught restricted at 16.1 meter).

Peaks for the Panamax size vessel are distinct for 70,000-80,000 dwt and 80,000-90,000 dwt. These vessels have very fixed size limits governed by locks of the Panama canal. Little change will be envisaged in the future within this size category unless the canal is expanded.

Within the smaller size of bulk carrier, there is a clear peak in the 50,000-60,000 dwt range, which is currently under-represented in the existing fleet. The increasingly popular Handymax vessels of around 55,000 dwt seem to replace many of the aging Handysize vessels in the fleet. This shift is the result of the port expansions and the improved economies of scale that can be achieved with the Handymax.

- Distribution of bulk carrier fleet by age

The trend of becoming larger in size can also be demonstrated by the bulk carrier average age in different categories. Based on figures of Clarksons intelligent network (2008), in number of vessels, up to 2008, there are 2518 out of 7132 vessels, i.e. about 35% of the world's bulkers, built before 1988. The biggest proportion of old vessels run for over 20 years falls upon the range of 10,000-40,000 dwt, while the smallest drops upon vessels larger than 100,000 dwt.

Stimulated by economies of scale, ship owners are in favor of ordering larger vessels. Around half of Handymax and half of Panamax were delivered after 1998. Since the early 1990s, there has been a surge of building larger vessels over 160,000 dwt, of which more than 60% were delivered after 1998.

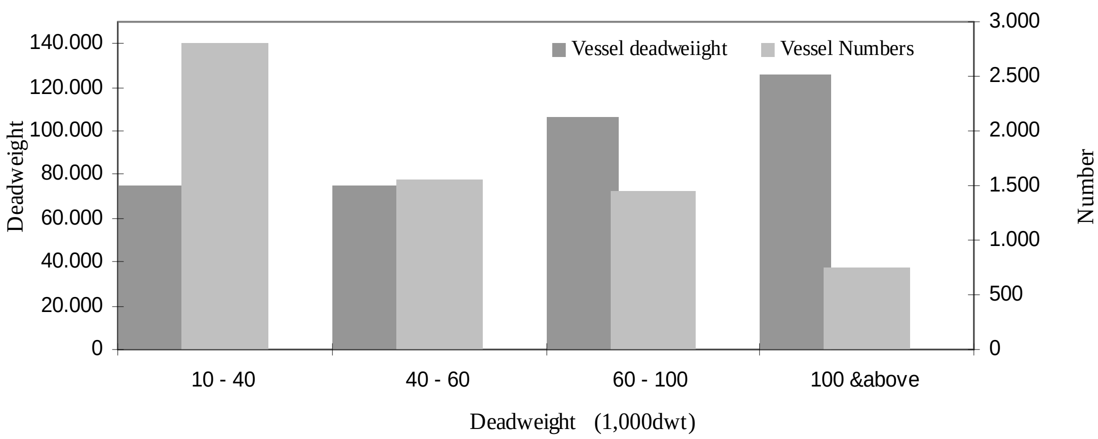

Figure 2.13: The distribution of bulk carrier classes (ship's number and deadweight)

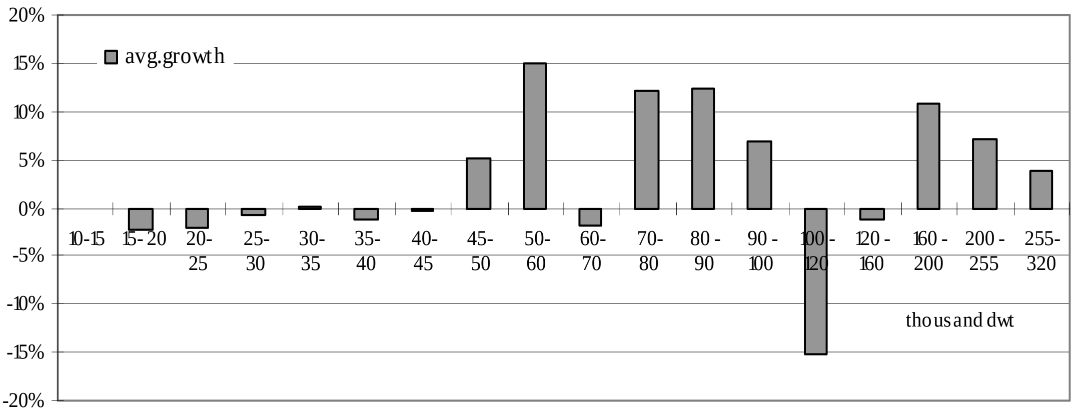

Figure 2.14: The average growth of bulk carriers in size from 1998 to 2008

2.2.3.2.Economic analysis of larger vessels

In order to explain the sizable growth of larger vessels in the past decades, the transport costs per unit is still used as an indicator in this part.

Differentiating Equation (2.2) with respect to DW gives

$$dQ_{tm} = Q_{tm} \cdot (1 - \frac{t_{p1}}{t})(\frac{dDW}{DW}) \tag{2.12}$$

Substituting Equation (2.12) into the differential equation of Expression (2.1), we have

$$da_t = a_t(\frac{dS}{S} - (1 - \frac{t_{p1}}{t}) \cdot \frac{dDW}{DW}) \tag{2.13}$$

It can be identified from Equation (2.13) that:

(1) For the same type of vessel, it is known that $dW_{h,m} / W_{h,m} < dDW / DW$ ($W_{h,m}$ indicates the lightweight of a ship), which reduces the building costs per unit and increases the earning capacity. Moreover, operational costs don't increase in proportion to the deadweight. Finally, we can get $dS / S <$ dDW / DW . Under the condition of sufficient cargo demand, the optimal ship, in terms of the lowest transport costs, is generally the largest ship possible due to the economy of scale (see also Buxton(1987)). Economy of scale in shipping is usually gauged by the annual costs per dwt, obviously shown in Table 2.3.

(2) The smaller the coefficient t_{p1} / t is, the lower transport costs per unit. The smaller coefficient t_{p1} / t implies higher handling rates at both loading and discharging ports, and/or the vessel with lower speed at voyages of longer distance. Comparing Equation (2.13) with Equation (2.4), it's clear that if $dV_s / V_s \approx dDW / DW$, the solution to improve transport capacity by raising the deadweight is more economical than the one by increasing the speed. This can explain why the past decades have witnessed the sharp expansion of the deadweight and the slow growth of the speed for dry bulk vessels.

Table 2.3: Operating costs and bunker costs for bulk carrier by classes in 2008

Ship Type	*Operating Costs($/pd)*	*Bunker Costs($/pd)*	*Costs Per Dwt Per Day*
Handysize	4670	12308	0.5659
Handymax	5255	16630	0.4863
Panamax	5745	17505	0.3321
Capesize	6525	30087	0.2441

Source: Drewry dry bulk forecaster (2008) and Clarkson intelligent network (2008)

2.2.4. Changes in lightweight and impacts on economic performance

In addition to the speed and deadweight, lightweight is another important technical indicator related to the economic performance of a ship. Changes in lightweight of dry bulk vessels in the past four decades have never been checked in the previous work, so it's worthwhile to investigate changes and their impacts on the transport costs and benefits of running vessels.

2.2.4.1. Changes in lightweight

The building costs are mainly determined by the raw material and man hours required for the steel structure, outfitting and power plant. For this type of studies it goes to far to split the vessel in subsystems and define the raw material part and man hour part per subsystem. However in order to compensate for changes in L, B, D, T, Cb, the installed power and RPM we decided to take the following approach based on the rough weight estimation method with the Lloyds equipment number E from 1962, described in Watson (1998) neglecting the accommodation. This weight estimation method is explained in Appendix A. The weight of a vessel according to this statistical approach with the main dimensions of the vessel as parameters enables us to set a benchmark for each vessel in the database. The results are shown in Figure 2.15.

Figure 2.15 illustrates changes in the lightweight for dry bulk carriers during the past decades from 1970 to 2008. It's interesting to find that the lightweight has the tendency to decrease, roughly 15% reduction during the past decades. The decrease in the lightweight means an increase in the deadweight if the total displacement remains constant. Shipowners are surely willing to pay more for bulk vessels with more deadweight based on the same displacement.

The lightweight of a vessel includes the weight of shell, machinery and outfitting, among which, the hull weight accounts for the biggest part of the total and the weight of the propulsion and power system the next. Therefore, triggers for changes in lightweight can be examined from the hull, which can be demonstrated by the block coefficient.

Block Coefficient (C_b) is the ratio of the volume of displacement (∇) to the volume of rectangular block $L_{bp} \times B \times T$, implying the fullness of the ship's hull. It is written by

$$C_b = \frac{\nabla}{L_{bp} \times B \times T} \tag{2.14}$$

Where L_{bp} means ship length between perpendiculars in meters; B ship moulded beam in meters and T ship moulded draft in meters.

The statistical information of the ship database shows that the average block coefficient of dry bulk vessels has increased slightly during the past decades, from roughly 0.82 in 1970 to 0.85 in 2008 (see Figure 2.16). In other words, the main measurement ($L_{bp} \times B \times T$) required for the unit displacement has decreased. It argues that if $L_{bp} \times B \times T$ becomes smaller, steel and machinery weight of lightship will be reduced as well, which is mostly true, see Aalbers (2007). Therefore, a decrease in lightweight may partly result from changing the hull form. Additionally, the reduced weight of engine installed, and the use of high tensile steel in the construction of a vessel, can also contribute to the decrease in lightweight of dry bulk carriers.

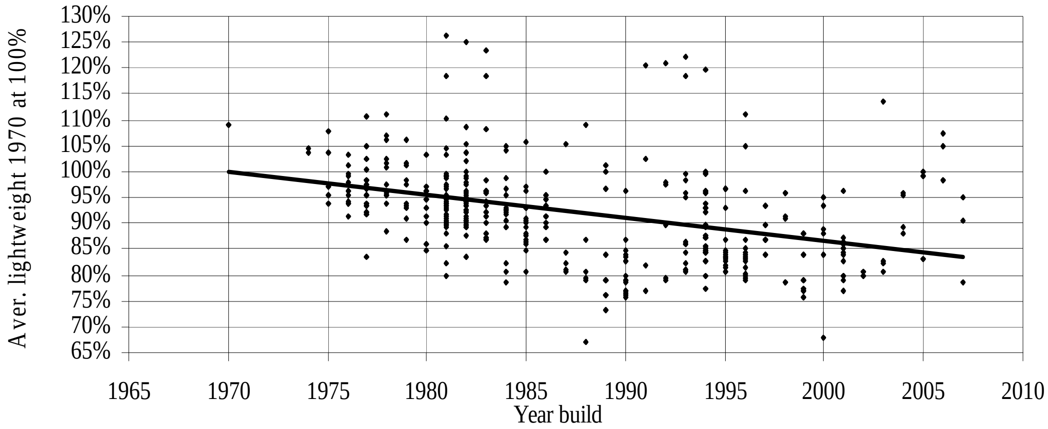

Figure 2.15: Lightweight changes during 1970-2008

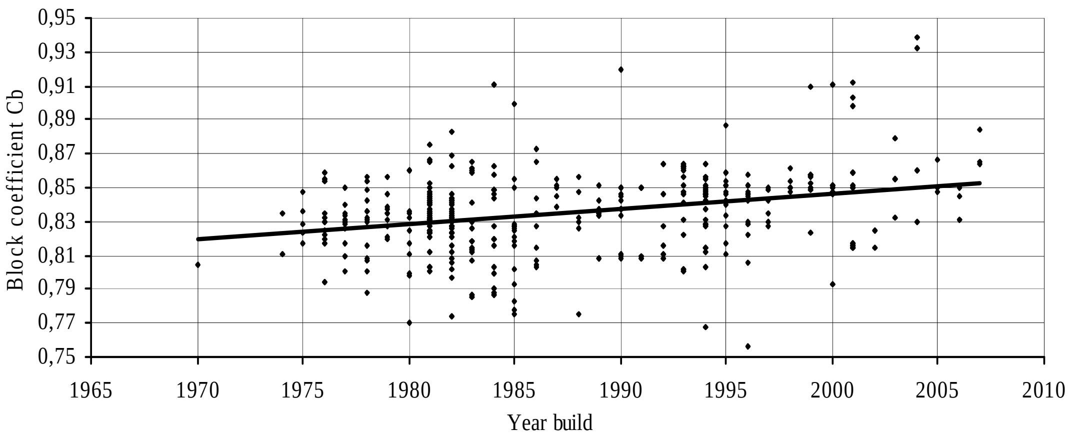

Figure 2.16: The trend of the block coefficient for dry bulk carriers

2.2.4.2.Impacts of changes in lightweight on the economic performance

Changes in lightweight have great impacts on the economic performance of a ship. Less lightweight means directly fewer material costs and labor hours. By keeping total displacement of a ship constant, reducing lightweight can always result in more deadweight. Generally a dry bulk vessel can run for 25 years or above, therefore, increasing deadweight has a long-term effect on the earnings. Consequently, a ship with less lightweight can be more competitive, due to a larger cargo carrying capacity.

The relationship between changes in lightweight and economic performance can be clarified by a sensitivity analysis. Let's take a Panamax carrier for instance and do some calculations based on the voyage database. Suppose a standard Panamax with 73,000 dwt and 85,880 tons in displacement, carrying 58,500 tons of soy bean, operates USG/North China (Dalian), which is 10,113 miles, at 14 knots burning about 35 tonnes/day laden and 31 tonnes/day in ballast. The bunker prices are kept at $515/t for IFO and $850/t for MDO. Suppose there is sufficient demand for shipping in the Panamax market. The empirical analysis reveals that a 5% reduction in lightweight leads to a 0.88% increase in deadweight, implying that the vessel has the potential to gain more revenues. A 0.88% more in deadweight will increase voyage costs by 0.44% per shipment, however, it will finally bring about a 2.34% increase in the total profits per year when the freight rate remains at 80$ per ton and the building prices remain the same (see Figure 2.17). The more reduction in lightweight, the probably more profits. Furthermore, it's obvious that the vessel with more deadweight at the same displacement benefits more from higher market price level. Consequently, the vessel with less lightweight has a greater earnings potential.

Shipowners are always willing to building a new ship with lighter lightship. However, sometimes ship owners need to pay more for a new building vessel with less lightweight due to advanced technology involved in ship design and construction, or less for an alternative with more lightweight, at the same displacement. If this is the case, before building a vessel, it is necessary for them to evaluate how much increase/decrease in building prices can be accepted for a new vessel with less/more lightweight at the same displacement. In our case, when a standard new Panamax vessel is worth US$60 million, it is not profitable to build an alternative with a 5% reduction in lightweight if the newbuilding price is increased by 2.11% more, and vice versa. Though the magnitude of increase or decrease varies with specific vessels, different market freight rate level, service requirements, etc, the approach is the same in other cases.

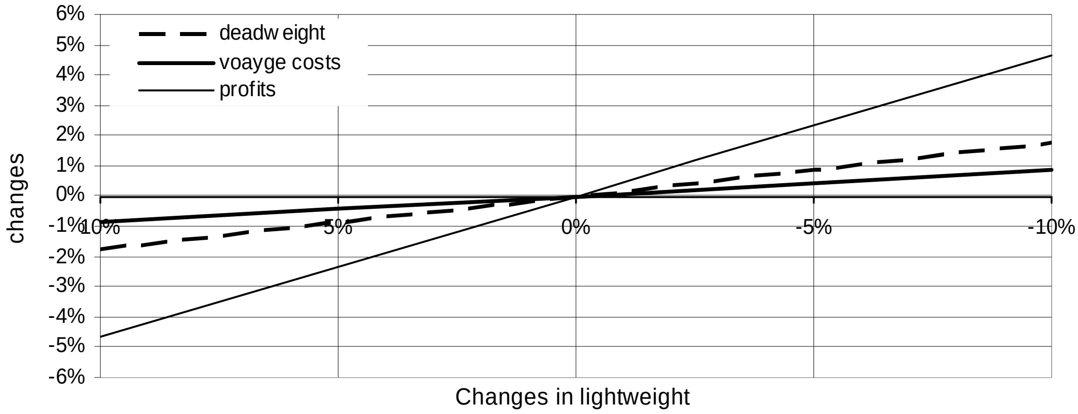

Figure 2.17: Sensitivity analysis of voyage costs and profits in response to the adjusting lightweight

2.2.5. Changes in fuel consumption and impacts on economic performance

As mentioned above, fuel consumption is one of the major cost factors that shipping companies will target for reduction. In operation, fuel costs are paid by charterers under time charter or bareboat contracts, who are willing to pay more for a fuel efficient ship or more common, less for a fuel inefficient ship, and also paid by ship owners under voyage contracts, who prefer fuel efficient ships in order to reduce voyage costs. All of these are triggers for fuel efficiency.

2.2.5.1. Changes in fuel consumption

Fuel consumption per ton-mile is taken as a first indicator to examine changes in fuel consumption of dry bulk vessels in the past decades. Suppose there are no speed changes in service, the fuel consumption per ton-mile can be simply calculated as follows:

$$F_{ton-mile} = \frac{FC_{day}}{24V_s \times dwt_{\max}} \tag{2.15}$$

Where $F_{ton-mile}$ denotes the fuel consumption per ton-mile; FC_{day} the fuel consumption per day; V_s the service speed and $dwt_{\max}$ the maximum deadweight.

It is revealed from Figure 2.18 that the vessel consumed much less fuel per ton-mile today compared with that of the 1970s. It's surprising to see that the fuel consumption per ton mile for dry bulk vessels dropped nearly by half from 1970 to 2008. In 1970, the average fuel consumption per ton mile was about 3×10^{-6} ton, while it's cut down to 1.5×10^{-6} ton in 2008. Ship owners no doubt want to operate with more speed or more cargo-carrying capacity at the same fuel consumption. However by measuring the fuel consumption per ton mile, one parameter was neglected: the speed. The higher the speed, the higher the fuel consumption per ton-mile. This is a technology independent factor. The design speed is an economical choice. In order to measure the fuel consumption performance of the vessel correctly we developed a benchmark per vessel which is determined by the required power at a certain design speed according to the method of Holtrop and Mennen (1979) as described in Appendix A, and by a fixed consumption per kWh of the engine set at such a level that the trend line is 100% in 1970. Corrected for the speed, the fuel consumption is nearly 60% of the 1970 level instead of the previously found 49% as a result of incorporating the effect of speed, as illustrated in Figure 2.19. These results confirm the earlier found higher design speeds in the 1970s.

It's not enough to only know that fuel consumption per unit has reduced greatly during the past decades. The technical innovations contributing to the considerable reduction in fuel consumption per unit should be investigated. By deepening the analysis, two important factors were found to trigger the considerable decrease in the fuel consumption per unit for dry bulk carriers. One is the technical innovation in hull form and propulsion system, and the other is the improvement in the engine technology. To what extent these two technical improvements contribute to the total reduction of the fuel consumption has been examined as follows.

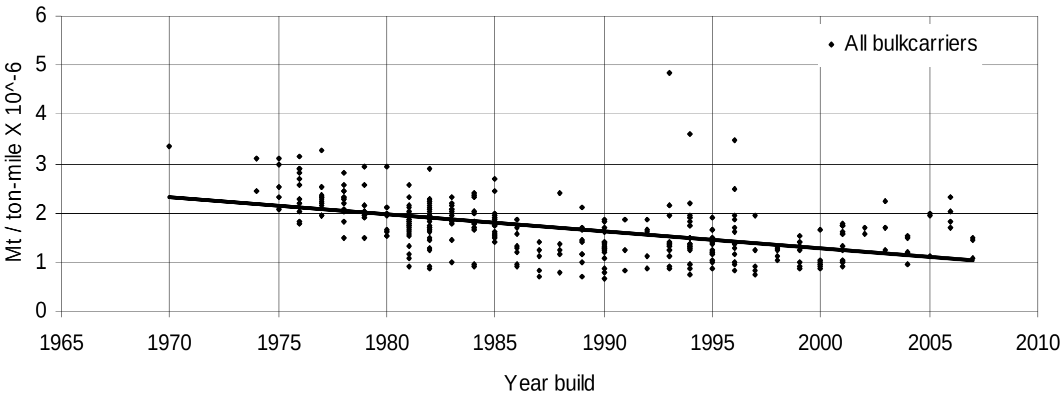

Figure 2.18: Changes in fuel consumption per ton-mile during 1970-2008

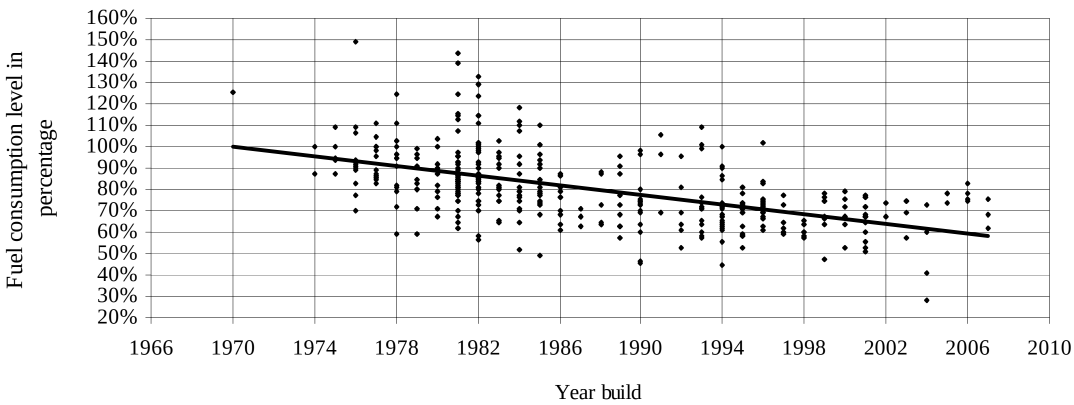

Figure 2.19: Changes in fuel consumption against the benchmark 1970-2008

- **Power installed**

The power installed determines the height of the investment in the diesel engine and influences the operational costs like fuel costs. It is determined by the hull and propeller performance. Testing the improvement requires a statistical benchmark based on the main dimensions of a vessel. The power prediction method created by Holtrop and Mennen (1979) is suitable for this purpose. Not all parameters used in the method could be used, because not all parameters are known. However, because all bulk carriers are full bodied vessels a lot of the unknown parameters could be estimated based on statistics or fixed on one value with only minor influences on the calculations. Our goal is to create a benchmark not to calculate the power requirement of the vessel. The impact of the bulb, transom and appendages were neglected. The estimation approach can also be found in Frouws (2010). Eventually each vessel gets a benchmark, the power installed, based on the state of the art from around 1979 and the design speed. The ratio of installed power versus benchmark can be found in Figure 2.20.

It's illustrated in Figure 2.20 that the average installed power on the shaft of the diesel engine has been decreased by around 25% since 1970. The changes in the main technical variables in the function of power estimation have been compensated, therefore, for the decreasing trend in the power is only triggered by the technical improvement of the hull shape and the propulsion system. It implies that due to improvements in the hull/propulsion system during 1970 till 2008, the fuel consumption has been decreased by around 25% of the total of 41%.

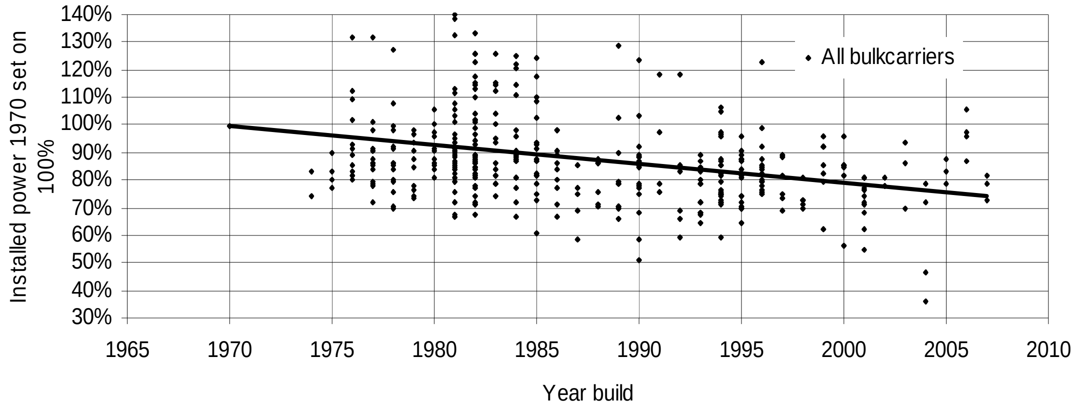

Figure 2.20: Changes in installed power during 1970-2008

- **Engine**

The fuel consumption has also been influenced by the improvements in diesel design. For small and Handysize bulk vessels, the selection of the main engine is not much distinct as for large bulk vessels. Four-stroke and two-stroke are both used. For large vessels, including Handymax, Panamax and Capesize, two-stroke engines are widely applied due to their efficiency, reliability and low maintenance costs, see Man B&W(2006).

The development of engine technology over the last decades is illustrated in Figure 2.21. The power density depends on the mean effective pressure and the mean piston speed, and is a measure of the 'technology' of the engine. Notably the product of those two parameters (bar*m/s) has increased a lot, from 29 bar*m/s for Sulzer RSD 58 in 1950 to 151.9 bar*m/s in 1996 for Sulzer RTA 96C, implying the power performance has been improved substantially during the past decades. Figure 2.22 reflects the trend of the specific fuel consumption of Sulzer engines in the past. For instance, the specific fuel consumption for the Sulzer RND 90 engine in 1967 was 208 g/kWh, while it dropped to 166 g/kWh for the Sulzer RTA 96 C two stroke engine in 1996, an important 20% reduction. Overall, the total efficiency of engines has been increased, up to over 50% for Sulzer RTA 96 C in 1996 from 40% for Sulzer RSAD 76. It's really a significant improvement and crucial for an efficient fuel consumption.

Therefore, the improvement in engine technologies also plays a significant part in pulling down the fuel consumption. Explained in the above, the specific fuel consumption has decreased by around 20% during the past decades. It can be concluded that out of 40% reduction in the fuel consumption per ton mile, about 20% is due to an improvement in the engine technology.

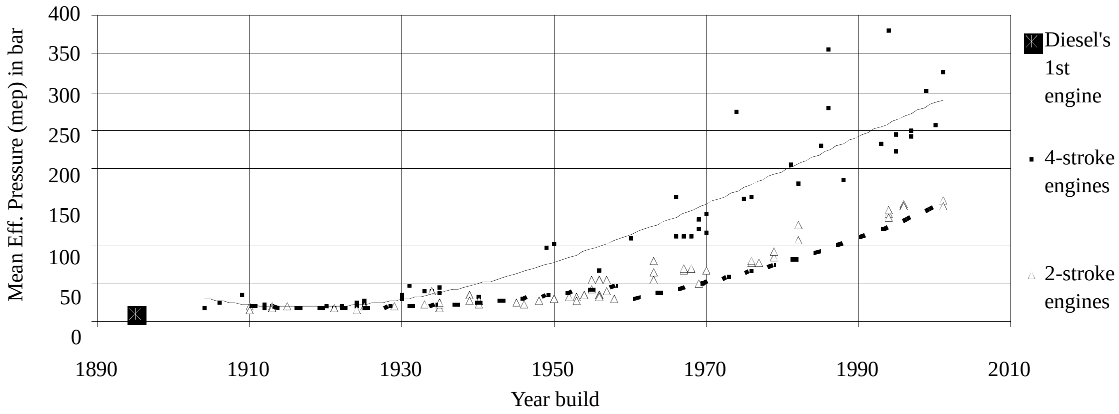

Figure 2.21: Power density trend of Diesel engines from 1910 to 2001

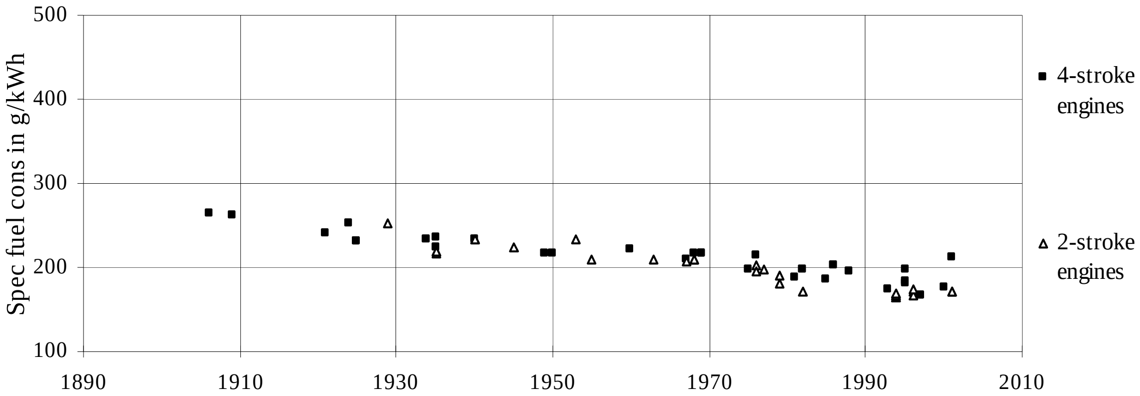

Figure 2.22: Changes in specific fuel consumption of diesel engines from 1910 to 2001
Source: Statistical information of Figures 2.21-2.22 from Prof. ir.D.Stapersma of TUDelft

To conclude the technology improvement, engine fuel consumption figures are really reliable figures. Improvements in hull design are much more complex. Together they account for a reduction of 41%, from which 18% till 23 % is due to the engine improvement (the latter for two stroke engines), see Figure 2.23 and 25 % hull / propulsion system improvement

The overall impression is consistent. The difference could be due to differences in the chosen sea-margins in the time, the database and not unimportant the wide spread in the data. This wide spread suggests wrong data. However a more reliable conclusion is that it reflects the extreme difficult and complex area of optimizing the hydrodynamic hull design, an area which is still only to be approached satisfactory with towing tank tests. Not all vessels have been tested and not all alternatives can be tested for reasons of economy.

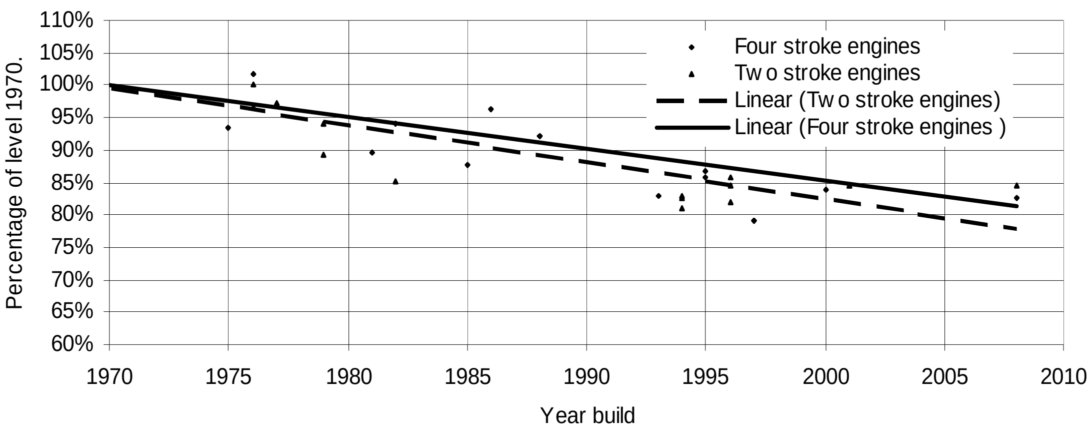

Figure 2.23: Relative changes in specific fuel consumption of engines from 1970 to 2008

2.2.5.2. Impact of changes in fuel consumption on the economic performance

The most significant component of the voyage costs is the fuel costs. The sensitivity of voyage costs in response to the fuel consumption per day is examined here, in order to clarify the influence of engine technology on the economic performance.

Suppose a Panamax with 73,000 dwt, carrying 58,500 tons of soy bean, operating USG-North China (Dalian), which is 10,113 miles, at 13.5 knots burning about 32 tonnes/day laden and 28 tonnes/day in ballast. Based on the voyage database, it can be calculated that when the bunker price for IFO is $515/t, a 5% reduction of fuel consumption per day, i.e.30.5 tonnes/day laden and 26.7 tonnes/day in ballast, can roughly bring about a 3.5% decrease in voyage costs, as well as 1.12% lower in required freight rate, and vice versa. Additionally, the higher the fuel prices, the more ship owners can benefit from fuel efficient ships. It can be concluded that a fuel efficient vessel is more competitive in freight rate and has the cost advantage for ship owners, or in other words, it has the potential to gain more earnings, see Figure 2.24.

However, shipyards always ask more for a new fuel efficient vessel, or less for a fuel inefficient vessel. Before building a vessel, ship owners have to evaluate how much increase/decrease in newbuilding prices can be accepted for a new vessel with less/more fuel consumption per unit. In our case, when a standard new Panamax vessel is worth US$60 million, it is not lucrative to build an alternative with a 5% reduction in fuel consumption per day if the newbuilding price is increased by 4.89% more, and vice versa. The approach is applicable in other cases.

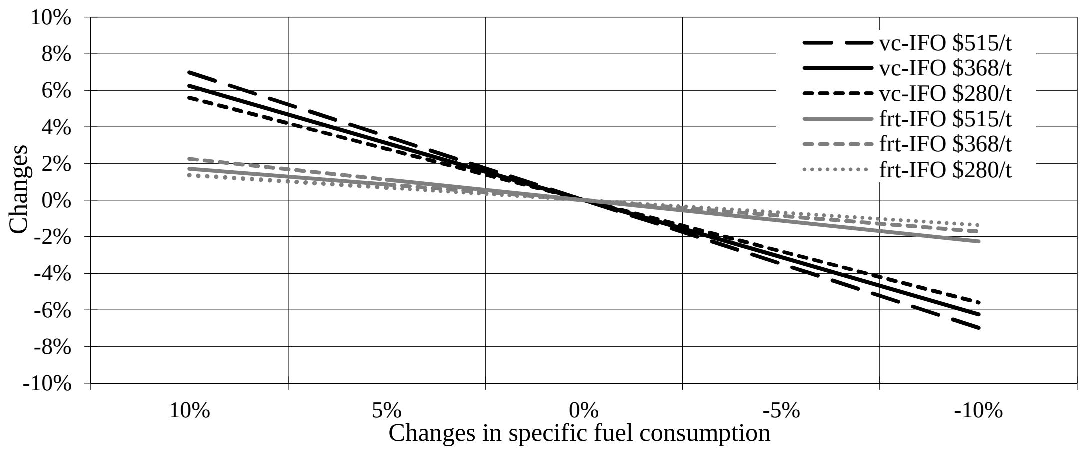

Figure 2.24: Sensitivity of voyage costs and freight rate in response to adjusting fuel consumption

Chapter 3. A Survey on the Econometric Modelling in the Dry Bulk Shipping

It is clear that in the past decades, the modelling of the dry bulk market has experienced the great development in modelling techniques and theories. As concluded by Glen(2006), the great research made by Beenstock and Vergottis marked a turning point in the modelling of the bulk market. Efforts in 1930s, 1950s, 1980s and the early 1990s focused on the structural economic models, relying on many variables, see for instance, Koopman (1939), Tinbergen (1959), Shimojo (1979), Norman (1979), Eriksen (1982), Wergeland(1981), Strandenes(1984) and Beenstock and Vergottis (1993).

Inspired by the developments in econometrics since 1990s, researchers have shifted their attention to the new econometric approaches and techniques. They have concentrated on the stationarity properties of the data and realized that neglecting the order of integration of time series has disastrous consequences for the empirical work and estimating structural models in level form is more problematic in this situation. Time series models with modern econometric techniques are found in Hale and Vanags(1992), Veenstra(1999), Kavussanos (1997), Kavussanos and Alizadeh (2002a), Kavussanos and Alizadeh (2002b), Kavussanos and Nomikos (1999, 2000, 2003), Alizadeh and Nomikos(2003) among others. For example, the general autoregressive conditional heteroskedasticity model has been used to examine the volatilities of mean values and/or variances of freight rates and second hand ship values, and the cointegration approach is applied in vector time series models due to the significant economic implications of the co-integration relations among variables. Specifically, if two freight rates series are co-integrated, there exists a constant mean in the long run relations. This information can be used to evaluate the relative movement of individual freight rate series on the basis of a comparison with this long term average.

In addition to techniques, it is worth noting that the expectations hypothesis attracts much attention and is always under scrutiny by the researchers, because the validity of the hypothesis needs to be tested so as to select appropriate models in the price determination or in the volatility evaluation.

Apart from the above mentioned, it is also found that the past research on explaining freight rates and ship prices focused on modelling the price levels. However, the volatility of freight rates and ship values and their stochastic properties have been attached more importance to and are examined by borrowed models in finance. And in order to investigate better the volatility, monthly data instead of annual data has been used. Moreover, the study on prices has been carried out more specifically, across different vessel size, for different contract duration, and under different market situations.

As for the freight derivatives markets, there are only a limited number of studies, in comparison to derivatives on other commodities, primarily due to the lack of data for empirical analysis. Cullinane (1992), Kavussanos and Nomikos (1999,2000, 2003), Kavussanos and Visvikis (2004) and Batchelor, Alizadeh and Visvikis (2007) contribute to the research of the freight derivatives markets.

The rest of the review is organized as follows. Section 3.1 presents the issues studied in the past decades and different models and techniques used in the freight market. Section 3.2 summaries the work done in the second-hand, newbuilding and scrapping markets. The derivatives market is reviewed in Section 3.3.

3.1. The freight market

This part takes a close look at the methodologies and models applied into the freight market including the market efficiency hypothesis test and the investigation of the volatility and interrelationship of freight rates and timecharter rates.

3.1.1. Efficient market hypothesis

In the dry bulk freight market, the efficient market hypothesis is always related to the term structure of freight rates and the risk premium. The term structure means the relationship between freight contracts with different duration. The study on the term structure relationship of shipping freight contracts is important because uncovering the true nature of such a relationship has significant implications, which include among others: decisions on entering short- or long-term markets by comparing time charter rates with the expected spot ones; decisions on hiring in or out vessels based on the degree of mispricing; modelling freight rate movements; risk return relationships in different segments of dry bulk freight market, and the inferences about the efficient pricing of freight markets, see Kavussanos and Alizadeh (2002a). Therefore, the efficient market hypothesis of the term structure between spot and period rates has attracted much attention of researchers.

Beenstock and Vergottis (1993) presume that the rational expectations (RE) and the efficient market hypothesis(EMH) are valid in the formation of time charter rates. The expected profitability of time charter contract should equal the expected profitability in the spot market over the duration of the contract. However, they do not attempt to investigate the validity of RE and EMH in the formation of period rates.

Veenstra (1999) provides a further investigation of the relation between spot and period freight rates for the ocean dry bulk shipping market. The present value model is used to express the period rate as expectations of future spot rates, which are estimated using a vector autoregressive modelling approach. It is concluded that the rational expectation hypothesis is valid for the pricing model used under the hypothesis.

The most thorough tests concerning the expectations hypothesis of the term structure come from Kavussanos and Alizadeh (2002a), who use a battery of tests to examine the validity of expectations hypothesis in the pricing of long-term contracts for different sizes of dry bulk carriers, including the perfect foresight spread test, the cointegration test and the VAR model test.

- **Cointegration test**

A set of non-stationary time series is cointegrated, if a linear combination of them is stationary. Cointegration means there exists a long-run equilibrium relationship among variables. Johansen (1991) procedure for testing for cointegration among variables is the most reliable approach and consequently and it is preferred by researchers. Other less popular and powerful approaches include Engle and Granger (1987) and Engle and Yoo (1987).

The spread, stated below, between earnings of one year time charter and one month freight contract, is a transformation suggested by Campbell and Shiller (1987), to incorporate the cointegrating relationship and result in a model with stationary variables.

$$S_t^{(12,1)} = TC_t^{12} - FR_t^{1} = \theta \sum_{i=1}^{11} (\delta^i - \delta^{12}) E_t(\Delta FR_{t+i}) \tag{3.1}$$

Where $S_t^{(12,1)} = TC_t^{12} - FR_t^{1}$ means the spread between earnings of one year time charter and one month spot contracts at time t, and $E_t(\Delta FR_{t+i})$ is the expected value of future changes in spot earnings.

If TC_t^{12} and FR_t are integrated series of order one $I(1)$, then ΔFR_{t+i} are the integrated series of order zero $I(0)$, so that the left side of Equation (3.1), i.e. the linear combination of TC_t^{12} and FR_t, must be the integrated series of order zero $I(0)$, which means TC_t^{12} and FR_t are cointegrated. So $S_t^{(12,1)}$ must also be stationary with the cointegrating vector $[1,-1]$ for the efficient market hypothesis to hold.

If TC_t^{12} and FR_t are cointegrated, the short-term dynamics between two variables can always be represented by a Vector Error Correction Model (VECM).

$$\begin{aligned}\Delta TC_t^{12} &= \gamma_{1,0} + \sum_{i=1}^{q} \gamma_{1,i}\Delta TC_{t-i} + \sum_{i=1}^{q} \lambda_{1,i}\Delta FR_{t-i} + \delta_1 (TC^{12}{}_{t-1} + \phi + \beta FR_{t-1}) + \varepsilon_{1,t} \\ \Delta FR_t &= \gamma_{2,0} + \sum_{i=1}^{q} \gamma_{2,i}\Delta TC_{t-i} + \sum_{i=1}^{q} \lambda_{2,i}\Delta FR_{t-i} + \delta_2 (TC^{12}{}_{t-1} + \phi + \beta FR_{t-1}) + \varepsilon_{2,t}\end{aligned} \tag{3.2}$$

If TC_t^{12} and FR_t are cointegrated with cointegrating vector [1,0,-1] in the system of equations (3.2), then the error correction term $(TC^{12}{}_{t-1} + \phi + \beta FR_{t-1})$ represents the spread, which can be regarded as the weak evidence for the efficient market hypothesis. Restrictions on the cointegrating vector can be tested using Likelihood ratio tests. In Kavussanos and Alizadeh (2002a), the efficient hypothesis restriction on the cointegrating vector is rejected by the empirical tests for three sizes of dry bulk carriers with contracts of different duration.

- **VAR model examination**

An alternative approach of forecasting expected changes in spot rates is the VAR model, proposed by Campell and Shiller (1987).

$$\begin{aligned}S_t^{(n,m)} &= \sum_{i=1}^{p} \mu_{1,i} S_{t-i}^{(n,m)} + \sum_{i=1}^{p} \mu_{2,i}\Delta FR_{t-i} + \varepsilon_{1t} \\ \Delta FR_t &= \sum_{i=1}^{p} \phi_{1,i} S_{t-i}^{(n,m)} + \sum_{i=1}^{p} \phi_{2,i}\Delta FR_{t-i} + \varepsilon_{2t}\end{aligned} \tag{3.3}$$

The above VAR model can be rewritten as:

$$\begin{pmatrix} S_t^{(n,m)} \\ \Delta FR_t \\ \vdots \\ S_{t-p+1}^{(n,m)} \\ \Delta FR_{t-p+1} \end{pmatrix} = \begin{pmatrix} \mu_{11} & \mu_{21} & \cdots & \cdots & \cdots\mu_{1p} & \mu_{2p} & \\ \varphi_{11} & \varphi_{21} & \cdots & \cdots & \cdots\varphi_{1p} & \varphi_{2p} & \\ 1 & 0 & \cdots & & & & \\ 0 & 1 & \cdots & & & & \\ \vdots & \vdots & \ddots & & & & \\ 0 & 0 & \ldots & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 \end{pmatrix} \begin{pmatrix} S_{t-1}^{(n,m))} \\ \Delta FR_{t-1} \\ \vdots \\ S_{t-p}^{(n,m)} \\ \Delta FR_{t-p} \end{pmatrix} + \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \vdots \\ 0 \\ 0 \end{pmatrix} \tag{3.4}$$

Or a more compact form using companion notation can be stated as:

$$z_t = Az_{t-1} + v_t \tag{3.5}$$

Where A is the companion form of the VAR matrix. For all i time periods, the expected values of z given the available information set H_t, will be given by:

$$E[z_{t+i} | H_t] = A^i z_t \tag{3.6}$$

Therefore, $S_t^{(12,1)} = \theta \sum_{i=1}^{11} (\delta^i - \delta^{12}) E_t(\Delta FR_{t+i})$ can be rewritten as:

$$S_t^{(12,1)} = \alpha' z_t = \theta \sum_{i=1}^{11} (\delta^i - \delta^{12}) A^i \beta' z_t = S_t^{*(12,1)} \tag{3.7}$$

Where α' and β' vectors are the $2p\times1$ selection vectors, A is a $(2p\times2p)$ matrix of parameters together with zero and unit value elements, and v_t is a $(2p\times1)$ vector of residuals and zero elements. $S_t^{(12,1)}$ and $S_t^{*(12,1)}$ represent the actual spread and the theoretical spread respectively.

If the efficient market hypothesis is valid, $S_t^{(12,1)}$ and $S_t^{*(12,1)}$ should move close together over time. Hence, a testable implication of the hypothesis is that the theoretical spread and the actual spread should satisfy the restrictions that $\alpha = 0$ and $\beta = 1$ in the following equation:

$$S_t^{*(12,1)} = \alpha + \beta S_t^{(12,1)} + \varepsilon_t,\ \varepsilon_t \sim iid(0,\sigma^2) \quad (3.8)$$

However, Campbell and Shiller (1991) use another approach to test the efficient market hypothesis, that is the Variance-ratio. It means that if the theoretical spread $S_t^{*(12,1)}$ is the best forecast of the future changes of spot rates, then the variance must be equal to the variance of the actual spread $S_t^{(12,1)}$. Therefore, the ratio of the variances of these two spread series should be close to unity. $Var(S_t^{*(12,1)})/Var(S_t^{(12,1)})$ =1. The null hypothesis that the variance ratio equals unity is rejected in the empirical test using the bootstrap methods by Kavussanos and Alizadeh (2002a). So the efficient hypothesis is proved to be invalid again.

3.1.2. To investigate the risk premium

The risk premium is tied with the expectations theory of the term structure. In the freight market, a positive risk premium implies that the period time charter rate exceeds the expected TCE spot freight rate from voyage chartering during the same time period and vice versa. The previous research has tested the validity of expectations theory in the freight markets together with the risk premium. Veenstra(1999) postulates that ship-owners prefer voyage charters and require a (constant) positive risk premium to enter into period time charters to offset the loss in liquidity. This liquidity premium hypothesis is rejected by the empirical tests. Kavussanos and Alizadeh(2002a) attribute the failure of the expectations hypothesis to the existence of a time-varying risk premium and attempt to model it using an EGARCH-M approach.

$$TC_t^{12} - \theta\sum_{i=0}^{11}\delta^i FR_{t+i} = \varphi_0 + \varphi_1\sigma_t + \eta_t,\ \eta_t = \varepsilon_t + \sum_{i=1}^{11}\xi_i\varepsilon_{i+1},\ \varepsilon_t \sim iid(0,\sigma_t^2)$$

$$\sigma_t^2 = \exp(\alpha_0 + \sum_{i=1}^{p} b_i \ln\sigma_{i-1}^2 + \sum_{i=1}^{q} c_i g_{1,t-i} + \sum_{i=1}^{q} d_i g_{2,t-i}) \quad (3.9)$$

$$g_{1,t} = (\varepsilon_t.\sigma_t),\ g_{2,t} = [(|\varepsilon_t|.\sigma_t) - E(|\varepsilon_t|.\sigma_t)]$$

The results saw the negative and significant parameters (φ_1) of the standard deviation term in the mean equation for all size vessels indicating the existence of negative time-varying risk premium.

Adland and Cullinane (2005) suggest that the risk premium in the freight market in bulk shipping must be time varying. The paper discusses in detail the risk premium depending on the state of the spot freight market and the duration of the period charter in a systematic fashion by taking into account the risk types and the agents' perception of risk. The risk premium is summarized in their paper as follows in Table 3.1.

Table 3.1: Risk Premium in the Bulk Shipping Market

Risk premium summary				
	Weak freight market		Strong freight market	
Charter duration	Short-term	Long-term	Short-term	Long-term
Vessel utilization risk	--	-	+	-
Spot volatility and liquidity risk	--	-	?	?
Transportation shortage	0	+	++	+
Default risk	+	+	+	+
Technological/Legislative risk	0	-	0	-
(+=positive, ++=positive and larger magnitude, -=negative, --=negative and larger magnitude)				

Source: Adland and Cullinane (2005)

3.1.3. Pricing of the freight market

The relationship between freight rates and the demand/supply fundamentals has been the topic of much research in maritime economics since the early 1930s.

Koopman (1939) proposes the short-term supply curve, indicating the amount of transportation willingly supplied by the fleet at a given freight rate. A short-term supply curve is characterized by two distinct properties: very elastic when tonnage is unemployed and inelastic when tonnage is in full employment. The supply exceeds the demand, resulting in low freight rates, high laid-up, more unemployment legs and lower speeds of vessels. All of these lead to the elastic supply. When all the vessels are employed, the way to increase the supply in the short-term is through higher utilization of the existing fleet, such as higher speed, shorter ballast legs, reduced port time and delaying regular maintenance, see Strandenes (2004). When the vessel is operating close to the maximum capacity, the supply is almost inelastic and freight rates are pushed up by the demand until the newbuildings enter and balance the market.

The demand in bulk shipping is taken as independent of freight rates in classic literature. Eriksen (1982) analyzes the possible influence of freight rates on the demand for freight services and results suggest that the demand for services varies inversely with freight rates. Wergeland (1981) estimates an aggregate model of the world dry bulk freight market (Norbulk). Strandenes and Wergeland (1981) investigate the bulk demand efficiency and they suggest that the demand for transportation services will be more elastic with respect to the freight rates when they are at very high levels. They analyze that when freight rates are extremely high, the importer may try to find an exporter that is closer, in order to reduce transportation costs. As a result, the average transportation distance decreases, possibly leading to lower demand. Secondly, if the demand for a commodity is price elastic and the freight rate element in the CIF price is high, the implicit elasticity for transportation may be substantial due to the potential for substitution of the commodity (for instance, oil vs. coal). Thirdly, if the freight rate becomes extremely high in a particular bulk shipping segment, other vessel sizes/types, or even other modes of transportation such as pipelines, may become competitive. Strandenes (1984) reports the results of an investigation into the determinants of time-charter rates and second-hand prices. The study estimates the sensitivity of time charter rates to changes in short-term and long-term expected TCE.

Beenstock and Vergottis(1993) provide an excellent summary of the past and a thorough study on the modelling of the bulk shipping market. In Beenstock and Vergottis (1993), the freight rate is determined by the interaction of supply and demand.

$$q^s = f_1(F_v, FR/P_b, Z_s) \tag{3.10}$$

Where q^s represents the supply of dry cargo ton-miles; F_v is the active fleet in the dry cargo market, which excludes the fleet laid up but includes combined carriers in dry. The active fleet is a proportion of the total fleet, $1-\lambda$ and λ is a function of freight rates, bunker prices, operating costs and costs in lay-up. FR is the dry cargo voyage freight rate, P_b the index of unit voyage costs, Z_s is the vector of exogenous variables additionally influencing the supply of the ton-miles.

Demand is treated as an exogenous variable, and always equals supply. Hence: $q^d = q^s$. The maximum profits at optimum speed at time t are related to freight rates, bunker prices and operating costs.

$$R_t = k(FR_t^{1+\gamma})/(P_b^{\gamma}) - OC_t \tag{3.11}$$

Where γ reflects the technological relationship between the fuel consumption and speed and is equal to the price elasticity of freight market supply.

In the simple case of no additional exogenous variables,

$$q^s = F_v \cdot (FR / aP_b)^{\gamma}, a = 1/\gamma + 1 \tag{3.12}$$

The expected profitability of one-year timecharter, arranged at time t, for time charter rate TC_t, should be:

$$E_t R_{t+1}{}' = TC_t - E_t OC_{t+1} \tag{3.13}$$

While the expected profitability of the alternative operating on the spot market is:

$$E_t R_{t+1} = E_t (FR_t^{1+\gamma} / P_b^{\gamma}) - E_t OC_{t+1} \tag{3.14}$$

Thus by some simple manipulation, the time charter rate in logarithms can be written as:

$$\ln TC_t = (1+\gamma) E_t \ln FR_{t+1} - \gamma E_t \ln P_{bt+1} + \mu \tag{3.15}$$

Where μ is a risk premium.

3.1.4. Seasonality of the spot and timecharter freight rates

To investigate the seasonal behavior of shipping freight rates is very important. Kavussanos and Alizadeh (2001) examine the seasonal behavior of the dry bulk freight rates for different ship sizes and for freight contracts with different duration and also study the seasonality patterns under different market conditions.

$$\Delta X_t = \beta_0 + \sum_{i=2}^{12} \beta_i Q_{i,t} + \varepsilon_t, \varepsilon_t \sim iid(0, \sigma^2) \tag{3.16}$$

The above equation is used to model the seasonality of freight rates for different sizes of dry bulk vessels under contracts of different duration. Where ΔX_t represents the growth rate of the underlying series, Q_{it} reflect relative seasonal dummies, β_i are parameters of interest showing the seasonal rise or fall in the growth rates compared to the monthly average of the sample; β_0 is the constant and ε_t is the white noise error term.

The results show that tramp freight rates have a unit root at zero frequency, but not at seasonal frequencies. That means the existence of stochastic seasonality has been rejected and there is significant deterministic seasonality, which is regular seasonal patterns. The authors attribute the seasonal patterns to the nature and pattern of seaborne trade. More specifically, the seasonality during different market situations is modeled by Equation (3.17) as follows:

$$\Delta X_t = \beta_{1,0} d_{1,t} + \sum_{i=2}^{12} \beta_{1,i} (d_{1,t} Q_{i,t}) + \beta_{2,0} d_{2,t} + \sum_{i=2}^{12} \beta_{2,i} (d_{2,t} Q_{i,t}) + \varepsilon_t \tag{3.17}$$

Where $d_{1,t}$ and $d_{2,t}$ are state dummies:

$$\begin{cases} d_{1,t} = 1 \text{ and } d_{2,t} = 0 \text{ if } 1/12 \sum_{j=-6}^{5} \Delta X_{t+j} > 0 & \text{Expansion phase (good)} \\ d_{1,t} = 0 \text{ and } d_{2,t} = 1 \text{ if } 1/12 \sum_{j=-6}^{5} \Delta X_{t+j} \le 0 & \text{Contraction phase (bad)} \end{cases}$$

The results provide evidence in favor of an asymmetric effect of the seasonal behavior of freight rates series under different market situations. It implies that the seasonal fluctuations are sharper and more profound for the periods of market expansion than the periods of market contraction. However, the differences become smaller when the contract duration increases.

3.1.5. Interrelationships between sub freight sectors

It is well known that the dry bulk market is disaggregated by size, called Capesize, Panamax, Handymax and Handysize. Each size vessel is involved in the transportation of certain commodities, see Table 3.2. Vessels of adjacent size are used as substitutes especially when the freight rate in one sub market is higher than the other. Therefore, vessels of different sizes may overlap in their cargo transportation capabilities or even be linked through intermediate size vessels.

Beenstock and Vergottis (1993) investigate the spillover effects between tanker and dry bulk markets through the market of combined carriers, shipbuilding and scrapping markets using dynamic econometric models, and get some results. Firstly, the higher dry cargo rates attract combinations from the tanker market, reducing supply there, and this will consequently cause tanker rates to increase as well. Secondly, the higher dry cargo rates push shipyards to build more dry carriers, restraining the tanker fleet growth, which will also cause an increase in tanker rates and ship values. Thirdly, the higher dry cargo rates will lead to a withdrawal of dry cargo ships from the scrap market, thus picking up scrap prices and attracting more tankers to be destructed. This will consequently enhance tanker freight rates and ship values.

However, the combined vessels have dwindled since 1990 and only a small number of vessels are ordered these years, so it has very limited impact on both tanker and dry bulk markets. In addition, over the past years from 2000 to 2007, both tanker and dry bulk fleet grow rapidly by 24.5% and 38.1% respectively, and the demolition has kept at low levels since 2004 for tanker and dry bulk carriers. Consequently since the late 1990s, no significant spillovers between the tanker and dry bulk markets through combinations, shipbuilding and scrapped markets.

Alizadeh (2001) investigates the differences in spillover effects within the spot market compared with those of the period market and also studies the existence of volatility spillover effects from one sub sector to other sub sectors.

Table 3.2: The segments of the dry bulk market

Ship type	*Combined carriers*	*Capesize >100,000 dwt*	*Panamax 60-100,000 dwt*	*Handymax 40-60,000 dwt*	*Handysize 10-40,000 dwt*
cargoes	iron ore, coal, cereals, bigger cargo, parcels ⇔	iron ore, coal, cereals ⇔	iron ore, coal grain, bauxite phosphate,coke ⇔	Cereals, coal, coke, steels, Cement, potash, rice, sugar ⇔	Gypsum, forest prods, scrap, sulphur, steels, rice, salt

3.1.6. Time-varying volatility of charter rates

Models used to investigate the time-varying volatility of prices are usually the autocorrelated conditional heteroskedasticity (ARCH) or generalised autocorrelated conditional heteroskedasticity (GARCH), first developed by Engle (1982), and extended by Bollerslev (1986), together with their extensions, such as EGARCH, proposed by Nelson (1991). By using these models, the conditional means and variances of the data set can be modeled simultaneously. The main work in modelling the dynamics of price variances in the freight market can be seen in Kavussanos (1996a), Kavussanos and Alizadeh (2001), Chen and Wang (2004) and Lu et al (2008) among others.

Kavussanos (1996a) models the behavior of the average value of spot and time charter rates for three sizes of dry cargo vessels, and the volatility of the rate over time by using monthly data over the period of Jan 1973 to Dec 1992. The model employed in the research is as follows.

$$y_t = x_t'b + \varepsilon_t, \varepsilon_t \sim N(0, h_t)$$
$$h_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-1}^2 + \sum_{j=1}^{q} \beta_j h_{t-j} \qquad (3.18)$$

Where x_t' is a vector of independent variables, y_t the dependent variable, ε_t the error term with the expected mean of zero and non-constant normally distributed variance given by h_t. The error tem is modeled as a function of p past values of random errors and q past values of the conditional variances. The model is estimated using the maximum likelihood.

In modelling the aggregate freight rate index, ARCH(1) model is employed. In modelling freight rate of each ship size, GARCH(1,1) model is applied and independent variables used in the models include lagged values of relevant spot rates, bunker prices, industrial production and the stock of the world dry bulk fleet. For time charter modelling, the significant independent variables were lagged time charter and spot rates. Results in Kavussanos (1996a) reveal that risks in the freight and time charter markets are not constant over time, and the volatility is higher in the time charter market as opposed to the spot freight market. Comparison of volatilities of spot freight rates between different vessels shows that risks are in general higher in larger vessels, as smaller vessels serve more varied trades than larger ones with the additional benefit of fewer limitations on certain ports.

Chen and Wang (2004) estimate such a model using daily returns data for the period 27 April 1999 to 31 July 2003, for three dry bulk ship sizes at four different time charter series. The EGARCH model is mainly applied to investigate the leverage effect in the presence of the international bulk shipping market. The specification of EGARCH model in their paper can be seen as follows.

$$R_t = \beta_0 + \beta_1 R_{t-1} + \varepsilon_i, \varepsilon_t \sim N(0, \sigma_t^2)$$
$$\ln h_t = \alpha_0 + \alpha_1(|Z_{t-1}| - E|Z_{t-1}| + \delta Z_{t-1}) + \phi \ln h_{t-1} \qquad (3.19)$$

Where R_t is the daily return for each route at time t, ε_t is the error term assumed to be a white noise with mean zero and non-constant normally distributed variance given by h_t. The term Z is the innovation standardized by dividing the random error by the conditional variance.

They find that the EGARCH model reveals statistically significant leverage effects on for all cases, as well as confirming the significance of past conditional volatility in determining its current magnitude. Therefore, it was proved that the phenomenon of an asymmetric impact between past innovations and current volatility have inherently dwelled in the international bulk shipping market.

Lu et al (2008) examine the volatilities of freight rate indices for three types of dry bulk vessels by using daily figures over the period 1 March 1999 to 23 December 2005. The GARCH model showed that the shocks will not decrease but have the tendency to strengthen for all the daily return series. To examine the asymmetric characters of daily return volatility in different bulk shipping sectors and different market conditions, the sample was divided into two periods: one is from 1 March 1999 to 31 December 2002, the other is from 1 January 2003 to 23 December 2005; the EGARCH model was then applied to investigate the asymmetric impact between past innovations and current volatility.

The results show that the asymmetric characters are distinct for different vessel size segments and different market conditions and the main reasons may be the different flexibility and different commodity transport on different routes.

3.1.7. Conclusions and questions

The previous modelling work in the dry bulk freight market has been reviewed and some of the econometric work is listed in Table 3.3 to give a clearer picture.

Table 3.3: Examples of econometric modelling work in the freight market

Authors	Topics	Models	Data	Data Period	Conclusions
Beenstock and Vergottis (1993)	Pricing	Supply and Demand Structural Model	Fleet, bunker price, operating and lay-up costs, time charter rate	Annual data of 1962-1985	Determinants of time charter rates are active fleet, bunker price, voyage cost, freight rate and a risk premium
Veenstra(1999)	EMH	VAR	Freight rate and TCE	Oct 1980-Dec 1995	EMH Holds
Kavussanos (1996a)	Time-varying volatility	ARCH, GARCH	Freight rate and time charter rate	Jan 1973-Dec 1992	Time varying volatilities exit and risks are higher in larger vessels
Kavussanos and Alizadeh (2001)	Seasonality	SARIMA	Spot rate, 1-y and 3-y time charter rate	Jan 1980-Dec 1996	Deterministic seasonality, and an asymmetric effect of seasonal behavior under different market conditions
Kavussanos and Alizadeh (2002a)	EMH	PFS, VAR, VECM	Spot rate, 1-y and 3-y time charter rate	Jan 1980-Aug 1997	EMH rejected
Kavussanos and Alizadeh (2002a)	Risk Premium	EGARCH-M	Spot rate, 1-y and 3-y time charter rate	Jan 1980-Aug 1997	There exists a negative risk premium
Chen and Wang (2004)	Time-varying volatility	EGARCH	Daily TCT rate on each route	27 April 1999 to 31 July 2003	Significant leverage effect of daily returns on each route
Lu et al (2008)	Time-varying volatility	EGARCH	Freight rate indices	1 March 1999 to 23 December 2005	Distinct asymmetric impacts for different types of vessels and different market conditions

In the structural econometric models mentioned above, freight rates are determined by supply/demand fundamentals and timecharter rates are affected by freight rates and transport costs (both voyage and operating costs). Figures from Clarkson database show that over the period from 2003 to 2007, the dry bulk trade grew by 28.10% and the fleet increased by 29.85%. However, for Panamax vessels, one year time-charter rate increased by about 276%, the ship value of a 5-year old second-hand vessel rocketed by 223% and that of the newbuilding rose by 103.7%.

It seems there are no close relationships between freight rates and shipping supply/demand fundamentals, because facts show that freight rates or ship prices have defied the gravity, paying little attention to what fundamentals say. Therefore, there must be several other significant factors at work to drive ups and downs of freight rates, such as the market sentiment and other exogenous variables. What important elements should be considered in modelling charter rates and/or ship prices? What approaches should we employ to model shipping variables? How to model volatilities of freight rates and time charter rates for different types of dry bulk vessels? These questions need to be answered in the relevant chapters.

What's more, the previous research indicated that Capsize and Panamax markets are closely related. In addition to these two markets, Panamax and Handymax markets are to some extent correlated. The spillover effects will be investigated in further chapters by using econometric techniques, in both returns and volatilities between Capesize and Panamax markets, and between Panamax and Handymax markets.

3.2. The ship market

This part examines techniques and models already applied in the ship market, including the newbuilding, the sale and purchase and the scrapped markets, which are dealt with ship values/assets. Issues discussed in this part cover the market efficiency hypothesis test, the pricing of new and second-hand vessels, the volatility of ship prices, as well as the ordering, delivering and the scrapped volume.

3.2.1. Efficient market hypothesis

Before starting the survey on the modelling of ship prices, the expectations hypothesis should be studied. The difference among the studies on the ship price determination is the way they deal with the expectations about the future income generated by ships.

Strandenes (1984) assumes that expectations are semi-rational in the price determination of second-hand ship prices. Because she finds that the price is more influenced by the changes in the long-term equilibrium profits than changes in current operating profits, which is regarded as the support for the semi-rational hypothesis.

Beenstock and Vergottis (1993) assume that expectations hypothesis are valid in the second-hand and newbuilding market and models of ship prices are based on the assumption. It implies that the predicted ship values by the model should be equal to the expected prices made by the market participants. However, they don't test the validity of the hypothesis. Hale and Vanags (1992) propose a test based on the cointegrating approach and Granger-causality between prices for three sizes of bulk carriers using the data of 1979-1988. The results cast doubt on the validity of the EMH and RE in price formation in the dry bulk sector. Glen (1997) reexamines the expectations hypothesis in dry bulk carriers using Johansen's multivariate cointergration test for the period of 1980-1995 and the results are mixed. He attributes the link between prices for different size vessels to the existence of common stochastic trends rather than the failure of the EMH.

Kavussanos and Alizadeh (2002b) investigate the validity of EMH and RE in ship price determination over a relatively long period from 1976-1997 using the cointegration test and VAR approach, and test the risk premium through GARCH-M model. They conclude that the EMH in the second hand and newbuilding markets are both rejected and excess returns on shipping investments are highly predictable, reinforcing the rejection of the hypothesis.

$$P_t = \sum_{i=0}^{n-1} \left(\prod_{j=0}^{i} (1 + E_t r_{t+j+1})^{-1} \right) E_t R_{t+i+1} + \left(\prod_{j=0}^{n-1} (1 + E_t r_{t+j+1})^{-1} \right) E_t P_{t+n}^{sc} \tag{3.20}$$

Where $E_t P_{t+n}^{sc}$ and $E_t R_{t+i}$ are expected price and income at time $t+i$ and $E_t r_{t+j}$ is the expected discount rate at time $t+j$.

Campbell and Shiller (1987) show that above equation can be linearized around the geometric mean of $P(\overline{P})$ and $R(\overline{R})$. Using a first-order Taylor series expansion,

$$p_t = \sum_{i=0}^{n-1} \rho^i (1-\rho) E_t \pi_{t+i+1} - \sum_{i=0}^{n-1} \rho^i E_t r_{t+1+i} + \rho^n E_t p^{sc}{}_{t+n} + k(1-\rho^n)/(1-\rho) \tag{3.21}$$

Where $p_t = \ln P_t$, $E_t \pi_{t+i} = \ln E_t R_{t+i}$, $E_t r_{t+i} = \ln(1 + E_t r_{t+i})$, $E_t p^{sc}{}_{t+n} = \ln(E_t P^{sc}{}_{t+n})$, $\rho = \overline{P}/(\overline{P} + \overline{R})$, $k = -\ln(\rho) - (1-\rho)\ln(1/\rho - 1)$.

Then the spread between price and operating profits is given below:

$$S_t = \sum_{i=0}^{n-1} \rho^i E_t \pi r_{t+i+1} + \rho^n E_t S_{t+n}^{sc} + c \tag{3.22}$$

Where $S_t = p_t - \pi_t$, $\pi r_t = \Delta \pi_t - r_t$ and $S_t^{sc} = p_t^{sc} - \pi_t$.

Then the test on the hypothesis is carried out by making use of cointegration and VAR approaches.

3.2.2. Pricing of ship prices

This part focuses on the investigation in the modelling of new-built and second-hand vessels and the volatility of ship prices. By doing this, major factors in determining ship prices and models in estimating them should be filtered out.

- **The pricing models in the sales & purchase and the new-building and markets**

Beenstock and Vergottis(1993) investigate the modelling of second hand ship prices. Models can be seen as follows:

$$\begin{aligned} P_t F_t^d / W_t &= f(E_t \overset{+}{R}_{t+1} / P_t, E\overset{+}{P}_{t+1} / P_t, \overset{-}{r}) \\ P_t &= f(W_t \overset{+}{/} F_t^d, E_t \overset{+}{R}_{t+1}, E\overset{+}{P}_{t+1}, \overset{-}{r}) \\ P_t &= f(W_t \overset{+}{/} F_t^d, TC_t - \overset{+}{E}_t OC_{t+1}, \overset{+}{P}_{n_t}, \overset{-}{r}_t) \end{aligned} \tag{3.23}$$

Where P_t represents the ship value at time t, W_t is the wealth, F_t^d the stock demand for ships and at equilibrium it must be equal to the available tonnage in the market at time t. r the expected return on other investments.

From the equation, it's known that an increase of investment in ships or the loss of diversification in investment will raise the risk which requires a reduction in prices. While some of the increase in demand for assets associated with an overall increase in wealth is likely to spillover into ships and this increases prices. In addition, if the expected profits or future ship prices increase, the ship value at time t will be raised until the excess demand is eliminated.

Beenstock (1985) assumes that new and second hand ship prices are perfectly correlated and the new and second-hand ships are the same asset, only differing in age. Based on this assumption, Beenstock and Vergottis (1993) determine the newbuilding prices by the following equation:

$$P_{n_t} = k_t + P_{t+1} - \mu \tag{3.24}$$

$$(P_{n_t} = E_t P_{t+k} + k_t \; , P_{t+1} = -k_t + P_{n_t} + \mu \; , \mu = P_{t+1} - E_t P_{t+1})$$

Where P_{n_t} denotes the new-building prices at time t, k is the time lag between the order and the delivery. P_{t+k} means the second-hand ship price at time $t+k$.

However, the dominating factors in the new and second hand ship prices are different. The newbuilding prices may be more driven by cost factors, such as labour, raw materials, design, and exchange rates, whereas second-hand prices may be in turn more driven by market forces. Consequently, second hand values are more volatile and speculative than newbuilding prices.

- **The investigation of the dynamic volatility of second hand ship prices**

With the development of modern econometric techniques, researchers shift their attention to the volatility analysis of ship values instead of estimating prices using structural models, for recent limited studies in time series analysis in the second hand market are mostly dealt with volatility of prices.

Veenstra (1999) examines the stationarity and co-integration of time series of the second hand ship prices for various ship sizes. He investigates the long run cointegrating relations among four variables including second-hand prices, time charter rates, new-building and scrap prices. Two different second-hand prices are used in the whole study: 5 year old prices for the replacement transactions and 10 year old prices for speculative transactions.

Kavussanos (1997) examines the dynamics of conditional volatilities in the dry bulk market for the second hand ships. The paper specifies the conditional mean of the variable of interest, the conditional variance of the variable, and the conditional density of the error term in the model. By employing time-series ARCH models, the author finds that prices of small vessels are less volatile than larger ones and the nature of this volatility varies across sizes. Panamax volatilities are mostly driven by old ‘news’, while new shocks are more important for Handysize and Capesize volatilities. Apart from these, conditional volatilities of Handysize and Panamax prices are positively related to the interest rate, while Capesize to time-charters.

SARMA-GARCH and SARIMA-X/GARCH-X (structural macroeconomic variables relative to shipping industry are introduced in the mean and variance) models are used to model rates of changes on second-hand ship prices. Empirical analyses show that latter model gives the better results.

Alizadeh and Nomikos (2003) have applied the EGARCH methodology to examine the price-volume relationships in the market for the second-hand dry bulk vessel.

(1) The lead-lag relationship between price changes and trading volume:

$$\begin{aligned} \Delta P_t &= \alpha_{1,0} + \sum_{i=1}^{p} \alpha_{1,i} \Delta P_{t-i} + \sum_{i=1}^{p} \beta_{1,i} V_{t-i} + \varepsilon_{1,i} \\ V_t &= \alpha_{2,0} + \sum_{i=1}^{p} \alpha_{2,i} \Delta P_{t-i} + \sum_{i=1}^{p} \beta_{2,i} V_{t-i} + \varepsilon_{2,i} \end{aligned} \tag{3.25}$$

Where ΔP_t denotes logarithmic changes in second-hand prices and V_t is the trading volume. The authors demonstrate that for their data, the hypothesis that price returns Granger cause trading volumes for all three ship types (Handysize, Panamax and Capesize) could not be rejected, but the reverse holds for the causal link between trading volume and price returns. These results were interpreted to mean that trading volume information did not contain significant predictive power in the presence of information on past and current returns.

(2) The relationship between the price volatility and the trading volume (EGARCH-X model)

$$\Delta P_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i \Delta P_{t-i} + \varepsilon_i , \varepsilon_t \sim N(0, \sigma_t^{\ 2})$$
$$h_t = \exp(\alpha_0 + b_1 \ln h_{t-1} + b_2 g_{1,t-1} + b_3 g_{2,t-1} + cV_{t-1}) \tag{3.26}$$
$$g_{1,t} = (\varepsilon_t . \sqrt{h_t}),\ g_{2,t} = [(|\varepsilon_t|.\sqrt{h_t}) - E(|\varepsilon_t|.\sqrt{h_t})]$$

Where h_t is the conditional variance; $g_{1,t-1}$ and $g_{2,t-1}$ are the standardized residuals, $\varepsilon_t . \sqrt{h_t}$, and the difference between $|\varepsilon_t|.\sqrt{h_t}$ and the expected value of $|\varepsilon_t|.\sqrt{h_t}$, respectively, and the coefficient of lagged trading volume in the conditional variance equation, c , measures the impact of trading volume on the conditional volatility of ship prices.

The EGARCH-X model is used to examine the relationship between price volatility and trading volume. The empirical study indicates there is a negative relationship between trading volumes and ship price volatility. When volumes increase in an illiquid market, the price volatility is reduced. As the trading activity in the market increases, one would expect more information to be available in the market, in turn improving the market transparency and reducing uncertainty and market volatility. Therefore, increases in the trading activity, probably due to speculative trades or asset-play, ensure that ship prices do not depart substantially from economic fundamentals, in turn leading to more efficient pricing and reducing the volatility.

3.2.3. Ordering and deliveries

Beenstock and Vergottis(1993) assume that the orderbook is influenced by two factors. The first is the length of the order book, which is the length of time over which current orders are planned to be depleted from the book. The second is the delivery rate every year. So the order book is modelled as:

$$Q_t = f(\overset{+}{P_{nt} / P_{1t}},\ \overset{-}{P_{nt}^{'} / P_{1t}^{'}}, Z_Q) \tag{3.27}$$

Where P_{nt} represents the newbuilding prices of dry cargo ships. $P_{nt}^{'}$ reflects the new building prices of tankers. P_{1t} denotes the dry cargo shipbuilding cost index and $P_{1t}^{'}$ is the tanker shipbuilding cost index.

Higher prices tend to increased planned delivery rate and they are also positively related to the length of the order book. The empirical work shows that a 10% increase in the ordering of last year results in a 8% increase of ordering this year. And a 10% increase of deliveries last year leads to a 5.5% reduction of ordering this year. And the ordering is positive to new-building prices of dry cargo ships and negative to those of tankers.

Adland and Strandenes (2007) propose that the ordering can not be described as a deterministic function of market variables. It is worth noting that the ordering is a strategic investment and there exists the interdependence of such investment, so there is apparent ‘herding behavior’. Authors use the Poisson distribution to describe the order volumes, but the empirical work indicates that Poisson process cannot fully account for the occasional large jumps.

When the orderbook is modelled, the deliveries are hypothesized to be a function of lagged orders, $D_t = \sum_{i=1}^{m} \omega_i Q_{t-i}$.

Tvedt (2003) develops a continuous-time stochastic partial equilibrium model of the freight and newbuilding markets. It is found that the resulting equilibrium freight rate process is close to that of a standard geometric mean reversion process and the rigidities in either the construction of new tonnage or yard capacity significantly contributes to the mean reverting property of freight rates and makes the empirical work in the tanker market. But the time-varying ordering and the scrapping behavior are not modelled in Tvedt(2003).

By the marginal costs being equal to the freight rate, the supply (in tonne miles) Q_t and the freight rate X_t at time t are given:

$$Q_t = k_t (\frac{Y_t}{k_t})^{e/(e+v+1)} (vw)^{-1/(e+v+1)} \quad (3.28)$$

$$X_t = (\frac{Y_t}{k_t})^{e(v-1)/(e+v-1)} (vw)^{e/(e+v-1)} \quad (3.29)$$

$$G_t(Y_t, k_t) = Y_t / k_t,\ X_t = \xi G_t^{\varsigma} \quad (3.30)$$

Where $Y_t = \mu Y_t dt + \sigma Y_t dZ_t$, $dZ_t \sim N(0,dt)$. Y_t denotes demand scalar and follows a geometric Brownian motion and Z_t increment of a standard Brownian motion. k_t is the total tonnage at time t , ξ= $(vw)^{e/(e+v-1)}$, $\varsigma = ^{e(v-1)/(e+v-1)}$.

Based on the Ito's lemma, the above equations are given as:

$$dG = \frac{\partial g}{\partial k} dK + \frac{\partial g}{\partial y} dY + 1/2 \frac{\partial^2 g}{\partial y^2} (dY)^2 = (\mu - a_t + \delta) Gdt + \sigma G dZ_t \quad (3.31)$$

$$dX_t = \frac{\partial x}{\partial g} dG_t + 1/2 \frac{\partial^2 x}{\partial g^2} (dG_t)^2 \quad (3.32)$$

Because $(dG_t)^2 = [(\mu - a_t + \delta)Gdt + \sigma G dZ_t]^2 = 0 + \sigma^2 G^2 (dZ_t)^2 + 0 = \sigma^2 G^2 dt$,

$dX_t = \varsigma(\mu + \delta + 1/2\sigma^2(\varsigma - 1) - a_t) X_t dt + \varsigma \sigma X_t dZ_t$

Where δ is the constant depreciation rate and a_t the delivery at time t of new tonnage in percent of the total fleet. The optimal construction level, a^* depends on G_t and X_t is determined by G_t, so the structure of the freight rate for an optimal chosen construction policy given by:

$$dX_t = \varsigma(\mu + \delta + 1/2\sigma^2(\varsigma - 1) - a^*(X_t)) X_t dt + \varsigma \sigma X_t dZ_t \quad (3.33)$$

Adland and Strandenes (2007) assume the newbuilding projects cannot be accelerated, postponed or cancelled. Conditional on the assumption above, the delivery volume can be known with certainty on the assumption that the volume is a stochastic variable depending on the volume of new orders placed and the time lag between order and delivery. And the time lag is a function of the market condition and order book on the date the order was ordered.

3.2.4. Conclusions and questions

The previous quantitative work in the dry bulk ship market has been checked and some of the econometric modelling work is listed in Table 3.4.

The models mentioned above show that second hand ship values are affected significantly by time charter rates, operating costs and newbuilding prices. Previous studies concerning second-hand ship prices are mostly made on the market before 2000. However, the dry bulk market has changed substantially since 2002. What are the dynamic relationships between time-charter rates, second-hand vessel prices and newbuilding prices under the changing market conditions? What are new features of volatilities of second-hand ship prices and newbuilding prices? These questions need to be re-investigated under the new market conditions.

Table 3.4: Examples of the econometric modelling work in the ship market

Authors	Topics	Approaches	Data	Data Period	Conclusions
Strandenes(1984)	Determination of second-hand prices	The present value equation	Second-hand prices of Panamax	Annual data of 1968-1981	Semi-rational expectation and secondhand prices are the weighted average of the short-term and long-term profits
Beenstock and Vergottis(1993)	Pricing second-hand prices	Supply/demand structural model	Ship value, active fleet, the expected returns	Annual data of 1960-1985	Determinants of second-hand prices are available tonnage, world GDP and the expected returns on other investments
Beenstock and Vergottis(1993)	Pricing new-building prices	Supply/demand structural model	Second-hand prices, time lag and risk premium	Annual data of 1960-1985	new and second hand ship prices are perfectly correlated
Hale and Vanags (1992)	EMH	Cointegration test	Second-hand prices	Oct 1979-July 1988	Serious doubt about the validity of EMH
Glen (1997)	EMH	Cointegration test	Second-hand prices	Oct 1979-July 1995	The evidence of supporting the validity of EMH is less clear
Kavussanos (1997)	The volatility	ARMA-ARCH, SARMA-X/GARCH-X	Second-hand prices	May 1976-Aug 1995	Time varying volatility exits across different size and a positive risk premia
Veenstra (1999)	Cointegration between ship prices and time charter rates	Cointegration test	Second-hand, newbuilding, scrap prices and time charter rates	Jan 1985-Dec 1995	Three long-run relations among a set of four variables
Kavussanos and Alizadeh(2002b)	EMH and risk premia	The present value model, VAR, VECM and GARCH-M	Second-hand, newbuilding, scrap prices and profits	Jan 1980-Dec 1997 for Capesize and Jan 1976-Dec 1997 for other types	EMH in second-hand and newbuilding markets rejected and a posive time-varying risk premia in the second-hand market
Alizadeh and Nomikos (2003)	Price-volume relationships	VAR, EGARCH-X	Second-hand prices and trading volumes	Aug 1991 to June 2002	Price returns Granger caused trading volumes and a negative relationship exists between trading volumes and the ship price volatility

3.3. The freight derivatives market

Risk management is extremely important in the bulk shipping industry characterized as highly volatile, capital intensive, cyclical and exposed to international economic environment. Shipping derivatives have the potential to offset freight or timecharter rate risks in bulk market. The spot and derivatives markets are correlated, so a comprehensive and detailed survey of the role and the impact of the freight derivatives on the spot market is helpful in explaining the price fluctuations and in understanding what kind of strategies shipping companies should take to control risks of operating in the spot market.

The leading research in the freight derivatives market can be seen in Kavussanos and Nomikos (1999, 2000, 2003), Kavussanos, Menachof and Visvikis (2001) , Kavussanos, Visvikis and Batchelor (2004), Kavussanos and Visvikis (2004) and Kavussanos, Visvikis and Menachof (2004) among others.

3.3.1. Unbiasedness hypothesis of the freight forward market

Kavussanos, Menachof and Visvikis (2001) show that FFA prices of one- and two-months prior to maturity are unbiased pre-dictors of the realized spot prices in route 1, 1A, 2 and 2A. However, the efficiency of the FFA prices three months prior to maturity gives mixed evidence, with routes 2 and 2A being unbiased estimators, while routes 1 and 1A being seemingly biased estimators of the realized spot prices. Thus, it seems that unbiasedness depends on the market and type of contract under investigation. Descriptions of routes 1, 1A, 2, 2A can be found in Appendix B.

In Kavussanos et al (2001), the vector error correction modelling(VECM) framework is used to test the unbiasedness hypothesis of FFA prices in the FFA market.

$$\Delta X_t = \mu + \sum_{i=1}^{p-1} \Gamma_i \Delta X_{t-i} + \prod X_{t-1} + \varepsilon_t,\ \varepsilon_t \left| \Omega_{t-1} \sim distr(0, H_t) \right. \tag{3.34}$$

Where X_t is the 2×1 vector $(S_t, F_t)'$ of log-spot and log-FFA prices respectively. Δ denotes the first difference operator, ε_t is a 2×1 vector of error terms $(\varepsilon_{S,t}, \varepsilon_{F,t})'$, following an as-yet-unspecified conditional distribution with mean zero and time-varying covariance H_t. Γ_i and $\prod$ are coefficient matrices.

- **To investigate the existence of cointegrating vectors**

Johansen and Juselius (1990) show that the coefficient matrix $\prod$ contains the essential information about the relationship between S_t and F_t Specifically,
Rank ($\prod$)=0, implying no cointegration relationship between S_t and F_t
Rank ($\prod$)=1, implying a single cointegrating relationship between S_t and F_t ,in this case, the coefficient matrix can be factorized into two matrices both with lower dimensions 2×1, α and β., such as $\prod = \alpha'\beta$. β is the vector of cointegrating parameters and α is the vector of error-correction coefficients.
Rank ($\prod$)=2, denoting that all variables in X_t are $I(0)$.
Johansen (1988) proposes two statistics to test the rank of $\prod$:

$$\lambda_{trace} = -T \sum_{i=r+1}^{n} \ln(1-\hat{\lambda}_i) \tag{3.35}$$

$$\lambda_{\max} = -T \ln(1-\hat{\lambda}_{r+i}) \tag{3.36}$$

Where $\hat{\lambda}_i$ are the eigenvalues obtained from the coefficient matrix $\prod$, T is the number of usable observations, λ_{trace} tests the null hypothesis that there are at most r cointegrating vectors against the alternative hypothesis that the number of cointegrating vectors is greater than r. $\lambda_{\max}$ tests the null hypothesis that there are r cointegrating vectors against the alternative hypothesis of $r+1$.

$$\begin{pmatrix}\Delta S_t \\ \Delta F_t\end{pmatrix} = \sum_{i=1}^{p}\begin{pmatrix}\Delta S_{t-i} \\ \Delta F_{t-i}\end{pmatrix} + \begin{pmatrix}\alpha_1 \\ \alpha_2\end{pmatrix}\begin{pmatrix}1 & \beta_1 & \beta_2\end{pmatrix}\begin{pmatrix}S_{t-1} \\ 1 \\ F_{t-1}\end{pmatrix} + \begin{pmatrix}\varepsilon_{1,t} \\ \varepsilon_{2,t}\end{pmatrix}, \begin{pmatrix}\varepsilon_{1,t} \\ \varepsilon_{2,t}\end{pmatrix} \sim distri(0, H_t) \qquad (3.37)$$

The empirical results indicate that FFA and the realized spot prices are cointegrated for all maturities and for all routes except for route 1 and 1A in the three-months maturity.

- **To test the appropriate specification of the model**

Johansen(1991) proposes the following statistic to examine the most appropriate specification, including an intercept term in the cointegrating vector against the alternative that there are linear trends in the level of the series.

$$-T[\ln(1-\hat{\lambda}_2 *) - \ln(1-\hat{\lambda}_2)] \sim \chi^2(1) \qquad (3.38)$$

Where $\hat{\lambda}_2 *$ and $\hat{\lambda}_2$ denote the smallest eigenvalues of the model that includes an intercept term in the cointegrating vector and an intercept term in the short run model, respectively. Acceptance of the null hypothesis indicates that the VECM in the above equation should be estimated with an intercept term in the cointegrating vector.

- **To test parameters restrictions using LR statistics test**

The parameters of cointegrating vectors are checked by the following LR statistic test, proposed by Johansen(1991) :

$$-T[\ln(1-\hat{\lambda}_1 *) - \ln(1-\hat{\lambda}_1)] \sim \chi^2(2) \qquad (3.39)$$

Where $\hat{\lambda}_1 *$ and $\hat{\lambda}_1$ denote the largest eigenvalues from the restricted and the unrestricted model, respectively, and T is the number of usable observations. The degree of freedom equals to the number of restrictions on β.

The empirical results indicate that FFA prices one-and two-months prior to maturity are unbiased predictors of the realized spot prices in all investigated routes. The efficiency of FFA prices in providing unbiased predictions of spot prices three-months prior to maturity gives mixed evidence, with routes 2 and 2A being the unbiased estimators while routes 1 and 1A are biased estimators of the realized spot prices.

3.3.2. To investigate the hedging efficiency of the FFA market

In finance, a hedge is an investment that is taken out specifically to reduce or cancel out the risk in another investment. Hedging is a strategy designed to minimize exposure to an unwanted business risk, while still allowing the business to profit from an investment activity. The hedging in shipping involves investment activities in the futures markets and the spot market.

The issue of the effectiveness of future and FFA contracts in hedging freight risk has been investigated in Kavussanos and Nomikos (2000). Firstly, the optimal hedge ratio has been yielded conditional on the information available at time $t-1$ as follows.

$$\gamma^* \big| \Omega_{t-1} = \frac{Cov(\Delta S_t, \Delta F_t \big| \Omega_{t-1})}{Var(\Delta F_t \big| \Omega_{t-1})} \qquad (3.40)$$

Where γ^* is the conditional hedge ratio, ΔS_t and ΔF_t are the logarithmic differences of spot and futures prices.

Then, the conditional second moments of the spot and future prices have been estimated by VECM-GARCH-X models, which are made to compute the covariance and variance of spot and forward prices.

$$\Delta S_t = \sum_{i=1}^{p-1} a_{s,i}\Delta S_{t-i} + \sum_{i=1}^{p-1} b_{s,i}\Delta F_{t-i} + \alpha_s z_{t-1} + \varepsilon_{s,t}$$

$$\Delta F_t = \sum_{i=1}^{p-1} a_{F,i}\Delta S_{t-i} + \sum_{i=1}^{p-1} b_{F,i}\Delta F_{t-i} + \alpha_F z_{t-1} + \varepsilon_{F,t},\ \varepsilon_t = \begin{pmatrix}\varepsilon_{S,t}\\ \varepsilon_{F,t}\end{pmatrix}\Big|\Omega_{t-1} \sim Student - t(0, H_t, v) \quad (3.41)$$

$$H_t = C'C + A'\varepsilon_{t-1}\varepsilon'_{t-1}A + B'H_{t-1}B + D'Z^2_{t-1}D$$

Time varying variances and covariances of spot and futures prices can be extracted from the estimation of multivariate GARCH models with VECM specification of the mean of variables.

Finally, one-step ahead forecasts of the hedge ratio have been performed. Before making forecasts of the hedging ratio, one-step ahead forecasts of variance $E(h_{FF,t+1}|\Omega_t)$ and covariance $E(h_{SF,t+1}|\Omega_t)$ should be performed as follows:

$$H_{t+1} = \begin{pmatrix} h_{SS,t+1} & h_{SF,t+1} \\ h_{FS,t+1} & h_{FF,t+1}\end{pmatrix} = \begin{pmatrix} c_{11} & 0 \\ c_{21} & c_{22}\end{pmatrix}'\begin{pmatrix} c_{11} & 0 \\ c_{21} & c_{22}\end{pmatrix} + \begin{pmatrix} \alpha_{11} & 0 \\ 0 & \alpha_{22}\end{pmatrix}'\begin{pmatrix}\varepsilon_{S,t} \\ \varepsilon_{F,t}\end{pmatrix}\begin{pmatrix}\varepsilon_{S,t} & \varepsilon_{F,t}\end{pmatrix}\begin{pmatrix} \alpha_{11} & 0 \\ 0 & \alpha_{22}\end{pmatrix}$$
$$+ \begin{pmatrix} \beta_{11} & 0 \\ 0 & \beta_{22}\end{pmatrix}' H_t \begin{pmatrix} \beta_{11} & 0 \\ 0 & \beta_{22}\end{pmatrix} + \begin{pmatrix} d_{11} \\ d_{22}\end{pmatrix} z_t^2 \begin{pmatrix} d_{11} & d_{22}\end{pmatrix} \quad (3.42)$$

The one step ahead forecast of the hedge ratio is computed as:

$$E(\gamma^*_{t+1}|\Omega_t) = E(h_{SF,t+1}|\Omega_t) / E(h_{FF,t+1}|\Omega_t) \quad (3.43)$$

3.3.3. The effect of FFA trading on spot price volatility

Kavussanos, Visvikis and Batchelor (2004) examine whether the introduction of FFA trading has an impact on the spot market volatility and if so, how it influences the volatility. GJR-GARCH models, see below, are used in the analysis for pre-and post-FFA periods. Route 1, route 1A, route 2 and route 2A in Panamax shipping sector are selected to make the empirical study.

for pre-and post-FFA periods separately

$$\Delta S_t = \phi_0 + \sum_{i=1}^{p-1} \phi_i \Delta S_{t-i} + \varepsilon_t,\ \varepsilon_t \sim iid(0, h_t)$$
$$h_t = a_0 + a_1 h_{t-1} + \beta_1 \varepsilon_{t-1}^2 + \gamma_1 \varepsilon_{t-1}^2 D_{t-1}^- \quad (3.44)$$

for the whole period

$$h_t = a_0 + a_1 h_{t-1} + a_2 D_1 h_{t-1} + \beta_1 \varepsilon_{t-1}^2 + \beta_2 \varepsilon_{t-1}^2 + \gamma_1 \varepsilon_{t-1}^2 D_{t-1}^- + \gamma_2 D_1 \quad (3.45)$$

The results of coefficients of a_1 and β_1 indicate that the conditional variance in all routes is time-varying. The coefficient of a_1 can be viewed as the old news and is of a decreased value in the post-FFA period, showing the an increase in the rate of information flow after the introduction of FFA trading, i.e. old information has less impact on today's price volatility. While the coefficient of β_1 can be regarded as the new information and has the higher value in the post-FFA trading, implying that information flows more quickly with the onset of FFA trading, i.e. new information has a greater influence on today's price changes.

The coefficients of γ_1 examines the asymmetric effects on the price changes. In route 1A, the statistically significant asymmetry coefficients (γ_1) are negative for all periods, implying that negative shocks produce a smaller response than positive ones of equal magnitude. In route 1, γ_1 becomes positive, which means the positive shocks elicit a greater response than negative ones. While in route 2, 2A, empirical analysis gives the mixed results for different periods.

$$D_{t-1}^{-} = \begin{cases} 1 & \varepsilon_{t-1} < 0 \\ 0 & otherwise \end{cases}$$

The impact of the onset of FFA trading is captured by the introduction of a dummy variable D_1 in the variance equation, (D_1 takes the value of unity).

The empirical results show that FFA trading has the impact on the conditional spot prices volatility. The hypothesis of $a_2 = \beta_2 = 0$ and that of $a_2 = \beta_2 = \gamma_2 = 0$ are both rejected by Wald test.

The coefficient γ_2 is negative for all routes (-6.01E-07,-4.97E-06, -1.62E-06,-8.05E-05 for route 1,1A, 2, 2A), reflecting a negative impact/stabilizing effect on the level of price volatility of the underlying spot market. And authors further investigate whether the introduction of FFA trading is the only cause of stabilizing spot market by incorporating the conditional variances of major economic indicators affecting the volatility of spot market.

$$h_t = a_0 + a_1 h_{t-1} + a_2 D_1 h_{t-1} + \beta_1 \varepsilon_{t-1}^2 + \beta_2 \varepsilon_{t-1}^2 + \gamma_1 \varepsilon_{t-1}^2 D_{t-1}^{-} + \gamma_2 D_1 + \sigma_1 G_t \qquad (3.46)$$

Where G_t denotes the conditional variance of economic indicators including S&P500 Composite Index (SPI), S&P500 Commodity Index (SPCI), London Brent crude oil Index(BCOI) and West Texas Intermediate (WTI). The paper gives mixed results about whether the reduction of volatility in the spot market is the direct consequence of FFA trading. Only in routes1 and 2, the reduction of volatility may be a direct consequence of FFA trading. And the results do not present a clear answer as to whether the reduction in the spot volatility, in routes 1A and 2A, is a direct consequence of FFA trading.

3.3.4. The lead-lag relationship between forward and spot markets in terms of returns and volatilities

The lead-lag relationship between the spot and forward markets illustrates how fast one market reflects new information relative to the other, and how well the two markets are linked. The issue is of interest to academics, regulators and practitioners, because firstly it is linked to the market efficiency and arbitrage. Secondly, the derivatives market potentially provides an important function of price discovery. If so, then derivatives prices should contain useful information about subsequent spot prices, beyond that already embedded in the current spot prices. Thirdly, if volatility spillovers exist from one market to the other, the volatility transmitting market may be used by market agents, which need to cover the risk exposure.

Kavussanos and Nomikos (2003) employ Johansen's framework (1988) on daily for BIFFEX forward and the underlying BFI to perform causality tests and impulse response analyses and find that the forward prices help discover future spot prices, and that forward prices discover new information more rapidly than the current spot prices. Furthermore, the information incorportated in futures prices, when formulated as a VECM, produces more accurate forecasts of the spot prices than the VAR, ARIMA and random-walk models.

Kavussanos, Visvikis and Menachof (2004) find a bi-directional relationship between spot and FFA prices collected one month prior to maturity. When increasing the time to maturity to two and three months, only the FFA prices correct a disequilibrium created by the previous period's deviations. FFA prices thereby are showed to lead spot prices.

Kavussanos and Visvikis (2004) examine the lead-lag relationship between forward and spot markets, both in terms of returns and volatility. Though such issues have been studied extensively in the financial economics literature, it is the first time that the research has been made thoroughly in the shipping derivatives market. In their paper, causality tests and impulse response analysis indicate that there is bi-directional causal relationship between spot and futures returns in all routes. The latter implies that FFA can be equally important as a source of information as spot prices. A closer examination of the results suggests that causality from FFA to spot returns runs stronger than the other way in all routes. Meantime, volatility spillovers are also investigated. Results from a bivariate VECM-GARCH-X model, indicate that, a. The FFA volatility spills over to the spot market in route 1; b. There is no volatility spillover in either market in route 1A; c. There is a bi-directional relationship as each market transmits volatility in the other in route 2 and 2A.

- **To examine the lead-lag relationships between spot and FFA returns**

In Kavussanos and Visvikis (2004), the cointegration relationship between spot and FFA price has been investigated by the VECM model, provided as follows.

$$\Delta X_t = \mu + \sum_{i=1}^{p-1} \Gamma_i \Delta X_{t-i} + \prod X_{t-1} + \varepsilon_t, \quad \varepsilon_t \big| \Omega_{t-1} \sim distr(0, H_t)$$

Where X_t is the 2×1 vector $(S_t, F_t)'$ of log-spot and log-FFA prices respectively, Δ denotes the first difference operator, ε_t is a 2×1 vector of error terms $(\varepsilon_{S,t}, \varepsilon_{F,t})'$, following an as-yet-unspecified conditional distribution with mean zero and time-varying covariance H_t. Γ_i and $\prod$ are coefficient matrices. Specifically, it becomes:

$$\begin{aligned} \Delta S_t &= \sum_{i=1}^{p-1} a_{S,i} \Delta S_{t-i} + \sum_{i=1}^{p-1} b_{S,i} \Delta F_{t-i} + a_S Z_{t-1} + \varepsilon_{S,t}, \\ \Delta F_t &= \sum_{i=1}^{p-1} a_{F,i} \Delta S_{t-i} + \sum_{i=1}^{p-1} b_{F,i} \Delta F_{t-i} + a_F Z_{t-1} + \varepsilon_{F,t}, \ \varepsilon_t = \begin{pmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \end{pmatrix} \sim distri(0, H_t) \end{aligned} \quad (3.47)$$

The empirical results show that ECT represents a mean-reverting price process (a_S is statistically significant and negative, while a_F is statistically significant and positive). For example, in response to a positive deviation from their equilibrium relationship at the period $t-1$, spot prices decrease in value in the next period while FFA prices increase in value in order to eliminate any imbalance. It can also be indicated from the results that there exists the two-way feedback causal relationship between two markets (both $b_{S,i}$ and $a_{F,i}$ are statistically significant) and the price changes from spot market produce larger shocks to the FFA market than FFA to the spot market ($a_{F,i} > b_{S,i}$).

In addition to the Granger causality investigation, impulse response analysis is made to have a more detailed insight on the causal relationship between two markets. Generalised Impulse response (GIR), proposed by Pesaran and Shin (1998) is applied to capture the reaction of FFA and spot prices to one standard error shock in spot price returns and FFA ones, respectively. In the spot market, the impact of a shock is more direct in spot rates than in FFA prices. The FFA prices adjust gradually to the equilibrium while overshooting is observed in spot rates. In the FFA market, FFA prices adjust immediately to the new equilibrium by a standard error shock, while spot rates move gradually and take longer to reach the equilibrium.

- **To examine the lead-lag relationships between spot and FFA volatilities**

The lead–lag relationship between spot and FFA volatilities is investigated through a multivariate Vector Error-Correction (VECM)-Generalised Autoregressive Conditional Heteroskedasticity (GARCH) model, and structural macroeconomic variables relative to the shipping industry are contained in the mean and variance equations. (Macroeconomic variables include: SPI is the S&P500 Composite Index; SPCI is the S&p500 Commodity Index; BCOI is the London Brent Crude Oil Index and WTI is the West Texas Intermediate crude oil).

$$\Delta S_t = \sum_{i=1}^{p-1} a_{S,i}\Delta S_{t-i} + \sum_{i=1}^{p-1} b_{S,i}\Delta F_{t-i} + a_S Z_{t-1} + \varepsilon_{S,t},$$

$$\Delta F_t = \sum_{i=1}^{p-1} a_{F,i}\Delta S_{t-i} + \sum_{i=1}^{p-1} b_{F,i}\Delta F_{t-i} + a_F Z_{t-1} + \varepsilon_{F,t},\ \varepsilon_t = \begin{pmatrix}\varepsilon_{1,t}\\ \varepsilon_{2,t}\end{pmatrix} \sim distri(0, H_t) \quad (3.48)$$

$$H_t = A'A + B'H_{t-1}B + C'\varepsilon_{t-1}\varepsilon_{t-1}'C + S_S'\mu_{s,t-1}\mu'_{s,t-1}S_s + S_F'\mu_{F,t-1}\mu'_{F,t-1}S_F + E'(z_{t-1})^2 E$$

The empirical results in Panamax routes 1, 1A, 2 and 2A indicate that:

- The past shocks (new information) have a greater impact on the spot rather on the FFA volatility, while the past volatility (old information) has a greater impact on the FFA rather on the spot market.
- Spillover effects: For route 1, there is a unidirectional spillover effect from FFA to the spot market; For route 1A, there is no spillover effect from one market to the other. The discrepancy in the results between returns and volatility in routes 1 and 1A is attributed to the thin trading in terms of FFA contracts. For route 2 and 2A, there are bi-directional relationships in volatility spillovers, and the effect of shocks in the spot market on the FFA volatility is larger than that on the spot market volatility induced by the shock in the FFA market.
- The volatility persistence: In routes 2 and 1A, FFA price shocks seem to have a greater effect on the FFA volatility than that of spot price shocks on spot volatility. In route 2A, spot prices shocks seem to have a greater effect on the spot volatility than that of FFA price shocks on the FFA volatility. In route 1, the volatility of the FFA prices is not time-varying and there is no persistence in the FFA volatility.

3.3.5. To forecast the spot and FFA prices

Forecasting freight prices in dry bulk markets has attracted much interest of researchers, such as Cullinane (1992), Cullinane, Mason and Cape (1999), Kavussanos and Nomikos (1999, 2003) and Batchelor, Alizadeh and Visvikis (2007). This limited amount of literature is dealt with the performance of popular time series models in predicting spot and forward/future prices on major seaborne freight routes. The forecast performance of different models can be summed up as follows.

Futures: Future prices one and two months before maturity are unbiased forecasts of the realized spot prices, whereas a bias exists in three months futures prices. For 1-month ahead forecasts of the spot prices, the VECM provides better forecasts than the futures prices, ARIMA, Random Walk and Hot-Winters. While for 2- and 3-month ahead forecasts of the spot prices, futures prices outperform other models considered, see Kavussanos and Nomikos (1999).

ARIMA: Cullinane (1992) finds that ARIMA models provide the most accurate forecasts of the BFI for a forecast horizon up to 7 days. Batchelor et al (2007) find that ARIMA models provide the better forecasts of forward prices than the spot prices. VAR, VECM and S-VECM models slightly outperform the ARIMA for predicting the spot prices, however, for the forward prices, ARIMA outperforms the other time series models at longer horizons.

The ARIMA ($p,1,q$) model for spot and forward freight rate is denoted as:

$$\Delta S_t = \alpha_{10} + \sum_{i=1}^{p} \alpha_{1,i}\Delta S_{t-i} + \sum_{j=1}^{q} \beta_{1,i}\varepsilon_{1,t-j} + \varepsilon_{1,t},\ \varepsilon_{1t} \sim distri(0, H_{1t})$$

$$\Delta F_t = \alpha_{20} + \sum_{i=1}^{p} \alpha_{2,i}\Delta F_{t-i} + \sum_{j=1}^{q} \beta_{2,i}\varepsilon_{2,t-j} + \varepsilon_{2,t}, \varepsilon_{2t} \sim distri(0, H_{2t}) \quad (3.49)$$

VECM: Kavussanos and Nomikos (1999) reveal that a VECM of spot and futures outperforms other time series models for forecasts up to 15 days ahead. The forecast performance of VECM is examined again in Kavussanos and Nomikos (2003), finding that the VECM generates the most accurate forecasts of spot prices, but not of futures prices. Batchelor et al(2007) offer more detailed analysis. They conclude that for the spot prices, both the unrestricted VECM and the restricted VECM (the restricted VECM is derived from VECM by successively eliminating statistically insignificant coefficients) marginally outperform the VAR models (it is itself a restricted version of the VECM) and greatly better than ARIMA models. For the forward prices, the VECM provides better forecasts at short horizons than ARIMA models, while at longer horizons, ARIMA gives more accurate results. However, as discussed by Clements and Hendry (2001), the VECM is not robust to structural change, because the equilibrium correction term forces variables to their average historical relationship, so long-term forecasts in particular may be inaccurate if the underlying relationship has shifted.

The bivariate VECM(p) model is of the form as:

$$\begin{aligned} \Delta S_t &= \alpha_{10} + \sum_{i=1}^{p} \alpha_{1,i} \Delta S_{t-i} + \sum_{j=1}^{p} \beta_{1,i} \Delta F_{1,t-j} + \gamma_1 (S_{t-1} + \delta_0 + \delta_1 F_{t-1}) + \varepsilon_{1,t}, \\ \Delta F_t &= \alpha_{20} + \sum_{i=1}^{p} \alpha_{2,i} \Delta F_{t-i} + \sum_{j=1}^{p} \beta_{2,i} \Delta F_{2,t-j} + \gamma_2 (S_{t-1} + \delta_0 + \delta_1 F_{t-1}) + \varepsilon_{2,t} \end{aligned} \tag{3.50}$$

Random Walk: in Kavussanos and Nomikos (1999), random walk model is considered as the benchmark model for comparison purposes. The model gives poor predicting performance, compared with futures prices and the VECM models for all horizons. Whereas it outperforms ARIMA models for 3-month ahead forecasts, and this is reversed for 1- and 2-month ahead forecasts.

Holt-Winters: The Holt-Winters model has the worst forecasting accuracy of BFI over all forecasting horizons, as tested by Kavussanos and Nomikos (1999). They argue that this poor performance can be attributed to the stochastic properties of the BFI series.

3.3.6. Conclusions and questions

Some of the empirical modelling work in the freight forward market can be seen in Table 3.5. It can be concluded from the review that FFA prices can be equally important as sources of information as spot prices in commodity markets. It seems that FFA prices contain useful information about the subsequent spot prices and tend to reflect new information more rapidly than spot prices in all routes due to the limitations of short selling and higher transactions costs in the spot market. Additionally, FFA prices can be used as price discovery vehicles and the better understanding and modelling of FFA price returns and variance dynamics can contribute to control risks and make better decisions, such as ship chartering and budget planning decisions.

However, it is known from quite a few shipowners, charters and shipbroking companies that during these years, few shipping companies would like to use FFA as an effective hedging tool to cover the price risks in the spot market, More often, they speculate between both markets, which can be partly responsible for the slump and surge of freight rates in the spot market. For example, suppose a shipowner buy forward timecharter rates at the negotiated price with another counter-party in the FFA market, he will subsequently charter in vessels with high prices in order to push up price levels in the spot market. Assume at the expiration date, the shipowner has good luck, the settlement price is finally increased to be much higher than the contract price, then the shipowner will gain huge price difference in the forward market.

Therefore, FFA tends to have no stabilizing impact on the price volatility due to high speculation during these years, which is contrary to the conclusions in Kavussanos and Visvikis (2002). The relationships between FFA and spot prices and the prediction of prices in both markets need to be investigated again under different market circumstances.

The previous work also presents different forecasting performance of various forecast models. However, forecast models have their own application limitations. There will never be a generalised model that can be applicable for predicting prices in different markets. An ARIMA model outperform a VAR and a

VECM in predicting forward prices at longer horizons. While at shorter horizons, a VECM model can give better results. For forecasting spot prices, a VECM model performs better than a VAR model.

It is still a challenge for the econometric models such as ARMA, VECM, VAR models to forecast exactly the fluctuations or levels of indices and prices, because any misspecifications of models and variables, unreliable database or statistics inference can lead to the biased results and consequently the failure in forecast. As a consequence, it is of great importance to select well specified models and variables before making the prediction.

Table 3.5: Examples of econometric modelling work in the freight derivatives market

Authors	Topics	Approaches	Data	Data Period	Conclusions
Kavussanos, and Nomikos (1999)	Pricing function of freight futures	VECM, ARMA, RW, Holt-Winters	Monthly spot and futures of BFI	1m: 1988:07-1997:04 2m: 1991:12-1997:04 3m: 1988:03-1997:02	Futures prices provide the best forecasts among various forecasting models
Kavussanos and Nomikos (2000)	The hedging efficiency of futures of BIFFEX	VECM-GARCH-X	Weekly spot prices on routes 1&1A, and futures prices	23 Sep 1992-31 Oct 1997	Superior hedge ratios are obtained
Kavussanos, Menachof and Visvikis (2001)	Unbiasedness hypothesis of FFA prices	VECM	Spot and FFA on routes 1,1A, 2 &2A	Jan 1996-Dec 2000	1m and 2m-unbiased; 3m-biased on 1 and 1A; 3m-unbiased on 2 and 2A
Kavussanos, and Nomikos (2003)	Price discovery, causality and forecasting of futures	VECM, S-VECM, VAR, ARMA, RW	Daily spot and futures of BIFFEX	1 Aug 1988-30 Apr 1998	The price discovery role of futures strengthened, a VECM with futures yields the best forecasts
Kavussanos, Visvikis and Batchelor (2004)	The effect of FFA trading on spot price volatility	ARMA-GARCH-X	Daily spot and FFA prices on routes 1, 1A, 2 and 2A	1 Feb 1992-1 Nov 1999	The reduction of spot volatility may be a direct consequence of FFA trading in routes 1 and 2; In routes 1A and 2A, not clear
Kavussanos, Visvikis and Menachof (2004)	Unbiasedness hypothesis	VECM	Spot and FFA on routes 1, 1A, 2 and 2A	Jan 1996-Dec 2000	1m and 2m-unbiased, 3m-biased on 1 and 1A, 3m-unbiased on 2 and 2A
Kavussanos and Visvikis (2004)	The lead-lag relationships between FFA and spot markets	VECM-GARCH-X	Daily spot and FFA prices at routes 1, 1A, 2 and 2A	16 Jan 1997 to 31 Jul 2000 in routes 1 and 1A; 16 Jan 1997 to 30 Apr 2001 in routes 2 and 2A	A bi-directional causal relationship in returns between two markets; A unidirectional spillover from FFA to spot in route 1; no spillover effect in route 1A; bi-directional spillover effects in 2 and 2A; others see section 3.3
Batchelor, Alizadeh and Visvikis (2007)	Forecasting in spot and FFA markets	VECM, S-VECM, VAR, ARMA, RW	Daily spot and FFA prices at routes 1, 1A, 2 and 2A	Routes 1 and 1A: 1997:0116-2000:0731 Routes 2 and 2A: 1997:0116-2001:0430	FFA do help to forecast out-of-sample spot rates; the VECM is not helpful in predicting forward prices

Chapter 4. Modelling Price Behavior in the Freight Market

The investigation on the spot and the forward shipping prices in the freight market, including voyage rates, time-charter rates and the freight forward prices, is among the most important topics of the shipping industry. This chapter is devoted to the modelling and forecasting of shipping prices for three types of dry bulk vessels. In order to analyze and model shipping prices thoroughly, a great focus has been put on some issues, including the modelling of the rate variability; the term structure relations, the dynamic relationships of shipping prices between different sub markets for each ship size, the dynamic relationships between the spot and the forward prices and the prediction of daily and monthly spot rates at different routes in each market. The analysis and modelling are based on the methodology of modern econometric approaches described extensively in Appendix A, mainly the ARMA, the VAR and the VEC models, combined with the significant structural variables influencing the freight market.

It is worthwhile to note that firstly, the attention in this chapter is given not only to the shipping activity in different sub markets for each ship size, but also to the specific trading areas/routes and to the dynamic behavior of shipping prices under diverse shipping conditions. Secondly, the data with the higher frequency, i.e. daily and monthly data, have been used in the research. Thirdly, the behavior and forecasting performance of prices in the FFA market have been studied extensively in this chapter in order to explore their impacts on the spot freight market. Finally, time series models have been extended by the incorporation of crucial exogenous variables to improve the explanatory and forecasting performance of some time series models. The whole research yields substantial, interesting and promising results and provides useful information in shipping investment decisions for different market participants, including ship-owners and charterers.

4.1. The time-varying volatilities of rates in spot and period markets

The dry bulk cargo shipping market is a major component of international shipping market and is characterized by the high risk and volatility in light of uncertainty caused by factors such as the global economy, the volume and the pattern of seaborne trade and government policies. In this highly competitive market, sharp volatilities of spot freight rates or period rates make the prediction of shipping prices more difficult and bring great risks as well as opportunities to ship-owners and/or charterers. In the period from 1999 to 2010, the world bulk shipping market experienced intense changes, therefore, it is very necessary to investigate the volatile spot and period rates for dry bulk vessels under the complex market conditions.

The spot or period prices in the freight market have always been a topic of interest in the shipping industry, since to unveil the internal changing rules and the pattern of variation of these prices can help to forecast short-term price trends and to avoid risks. The past research on examining shipping prices concentrated primarily on modelling the level of spot and period prices, before and in the early 1990s, examples of which are Hawdon (1978), Wergeland (1981), Strandenes(1984), Beenstock and Vergottis (1993) among others. Glen (2006) points out that Beenstock and Vergottis (1993) provides an excellent survey of the past structural econometric modelling work in the bulk shipping industry. Since Beenstock and Vergottis (1993), researchers have shifted their attention on the stationarity properties of data and on the modelling of the price dynamics in terms of its volatility by making use of modern econometric techniques, examples are Kavussanos (1996), Kavussanos and Alizadeh (2001), Kavussanos and Alizadeh (2002a) and Lu et al (2008) among others. Their results are extensively described in Chapter 3.

The aim of this part is to examine the stationarity properties of monthly spot and period rates and make an in-depth investigation into the dynamic variation of these prices in Capesize, Panamax and Handymax markets. Such a comparison of time-varying risks between various size vessels will facilitate for example, the heavier weighting of shipowners' portfolios towards ship sizes which are relatively less risky, in a dynamic portfolio framework. Understanding the dynamics of the price volatility of each ship size may help predict more precisely the spot and period rates in different markets.

4.1.1. Methodology

In order to examine the time-varying behavior of prices, the Generalised Autoregressive Conditional Heteroskedasticity (GARCH) model, first developed by Engle (1982) and extended by Bollerslev(1986), will be used in this part. An abundance of empirical work has employed this methodology to capture the empirical regularity of non-constant variances in financial time series data, including the stock return data, interest rates, foreign exchange rates and price inflation rates.

GARCH models have been very successful in modelling the conditional volatility. Identification of a correct ARCH process may be achieved by examining the autocorrelation function of the squared residuals of the estimated ARIMA model. In practice, the appropriate lag structure for the conditional variance is decided both by the examination of the sample autocorrelation function of the squared residuals, and by Akaike (1973) (AIC) and Schwarz (1978) (SBIC) criteria in a series of nested ARCH/GARCH models.

A general form of the GARCH(p,q) model of Bollerslev (1986) can be seen in Appendix A. We restrict our attention to a GARCH (1, 1) since it has been shown to be a parsimonious representation of the conditional variance that adequately fits many economic time series. This specification can be expressed as follows.

$$\Delta X_t = \varphi_0 + \sum_{i=1}^{p} \varphi_i \Delta X_{t-p} + \varepsilon_t, \quad \varepsilon_t = \sqrt{h_t} z_t,\ z_t \sim iid(0,1)$$
$$h_t = \omega + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 h_{t-1} \tag{4.1}$$

Where ΔX_t means the change of variables, ε_t is a white noise error term with the usual classical properties, h_t is a time-varying variance, α and β are GARCH parameters.

Since h_t cannot be negative, Bollerslev(1986) derives conditions for non-negativity of $h_t : \alpha \geq 0$ and $\beta \geq 0$. The economic meaning of every parameter is: α reflects the intensity of outside shocks on market volatilities, a higher value of α indicates a more intense response to changes in the market and an inclination to disperse even more. β reflects the character of the memory of self-volatility. When $0 < \beta < 1$, a greater value of β indicates a longer persistence of the volatility. If $\beta > 1$, the volatility will enlarge the volatility in earlier stage by its own fluctuant system. The persistence of variance is measured by the sum ($\alpha + \beta$), the more this sum approaches unity, the greater is the persistence of shocks to volatility. If $(\alpha + \beta) > 1$, the GARCH process is non-stationary, and the shocks will not decrease but have the tendency to increase.

GARCH models have been extended to include exogenous variables in the specification of the conditional variance. Examples of the incorporation of structural variables into the conditional variance of financial price series are Engel and Rodrigues (1989), Glosten et al. (1990), Schwert (1989), Kavussanos et al. (1996a) among others. A GARCH$(1,1)$ model can be extended to be a so-called GARCH$(1,1)$-X model by incorporating exogenous variables into the conditional variance equation.

$$\Delta X_t = \varphi_0 + \sum_{i=1}^{p} \varphi_i \Delta X_{t-p} + \varepsilon_t, \quad \varepsilon_t = \sqrt{h_t} z_t,\ z_t \sim iid(0,1)$$
$$h_t = \omega + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 h_{t-1} + \delta Z_t \qquad (4.2)$$

Where ΔX_t means the change of variables, ε_t is a white noise error term with the usual classical properties, h_t is a time-varying variance, α and β are GARCH parameters, Z_t is the exogenous variable and δ is the parameter.

4.1.2. Description of data and statistical properties

The dry bulk shipping market is generally divided into three sub-markets by ship size: the Capesize, the Panamax and the Handymax/Handy markets. Each size ship is involved in different commodity trades and routes of the world. The majority of Capesize vessels are engaged in the transportation of iron-ore, mainly from Brazil and Australia, and also coal from Australia and South Africa. Panamax ships are used for iron ore exports from Brazil and Australia, coal exports from North America and Australia, grain exports from North America and Argentina, as well as bauxite and phosphate. Handymax vessels are used to transport grain from North America and Argentina to Africa and West Europe. We use monthly spot earnings, one-year time charter rates and three-year time charter rates in this part to examine and analyze the fluctuations in spot and period rates of these three sub markets.

In this part, spot rates are the time-charter equivalents of voyage charter rates in each market. One year time-charter rates/three year time-charter rates are chartering prices with one-year/three-year duration for the Capesize of 150,000 dwt, for the Panamax of 65,000 dwt and for the Handymax of 45,000 dwt. All the prices are obtained from Clarkson Research Studies. The price series for Capesize vessels cover the period from Dec 1991 to Dec 2010, yielding a sample of 229 observations. The sample period for the Panamax and Handymax vessels starts from Jan 1990 to Dec 2010 with 252 observations. The trends of all these variables can be shown in Figures 4.1-4.3. It can be seen that all these charter rates vary by vessel size but show similar stochastic behavior, however, the short run behavior is not identical and the different short term dynamics might be related to differences in each ship size market.

To analyze the short-term tendency of prices, the long-term tendency must be eliminated at first. Moreover the operators pay much more attention to the changing ratio of prices. The original data, subsequently, are switched into the logarithm ratio reflecting the changes of prices. The summary statistics of logarithmic first differences of spot and period rates during the sample period are presented in Table 4.1.

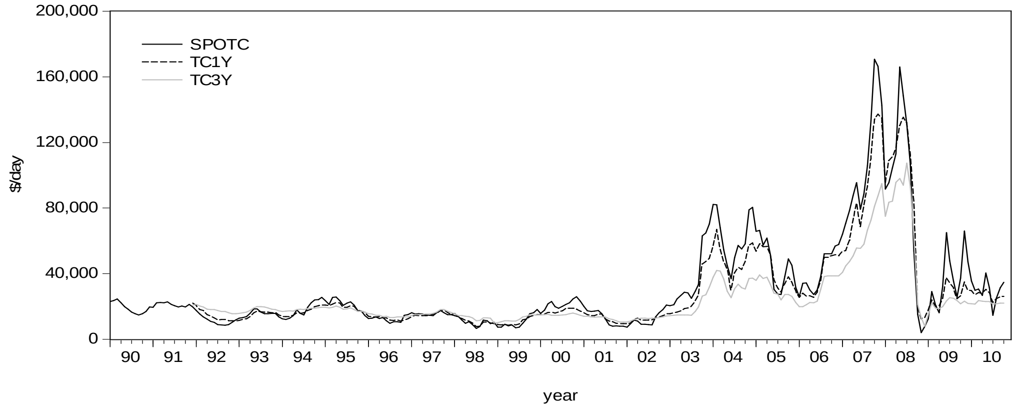

Figure 4.1: Spot rates (SPOTC), one-year time charter rates (TC1Y) and three-year time charter rates (TC3Y) during Dec 1991 to Dec 2010 for Capesize vessels

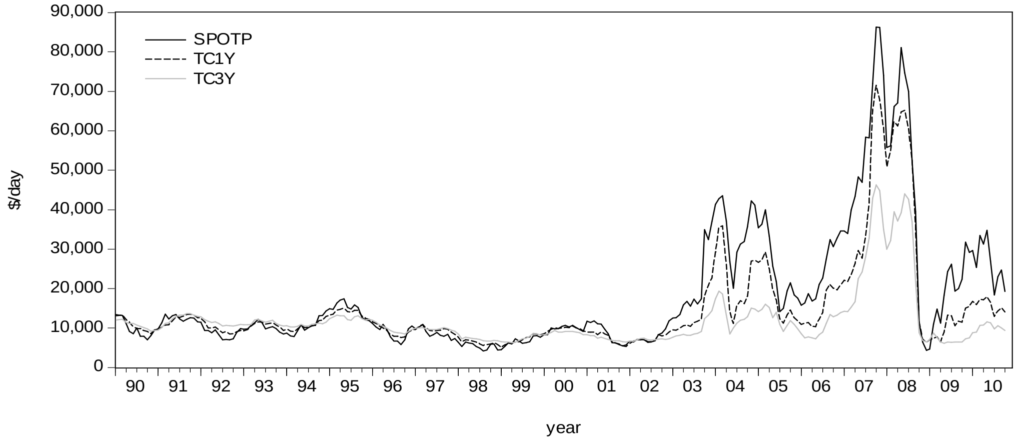

Figure 4.2: Spot rates (SPOTP), one-year time charter rates (TC1Y) and three-year time charter rates (TC3Y) during Jan 1990 to Dec 2010 for Panamax vessels

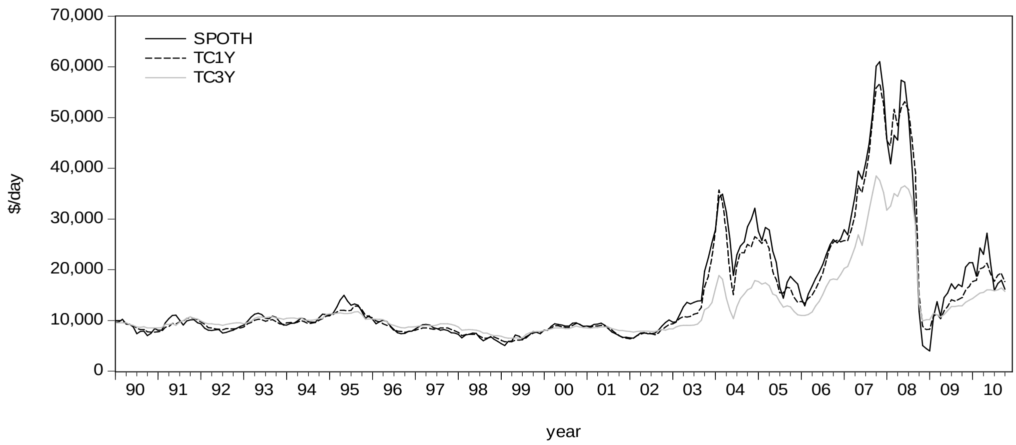

Figure 4.3: Spot rates (SPOTH), one-year time charter rates (TC1Y) and three-year time charter rates (TC3Y) during Jan 1990 to Dec 2010 for Handymax vessels

Table 4.1: Descriptive statistics of monthly rates of change in prices for three types of vessels

	N	Mean	Median	Std. Dev.	Skewness	Kurtosis	J-B	Q(20)	Q^2(20)	ADF(lags)	PP(lags)
Capesize											
ΔTCSC	228	0.00015	0.004	0.246	-0.865 [0.00]	9.97 [0.00]	4898 [0.00]	105.29	211.45	-12.11(1)	-11.41(26)
ΔTC1Y	228	-0.0006	0.006	0.155	-3.376 [0.00]	34.78 [0.00]	10005 [0.00]	76.06	7.08	-4.70(9)	-9.84(12)
ΔTC3Y	228	-0.0005	0.000	0.126	-2.784 [0.00]	31.69 [0.00]	8112 [0.00]	65.38	68.80	-9.72(2)	-8.94(17)
Panamax											
ΔTCSP	251	0.0008	0.007	0.180	-0.84 [0.00]	13.99 [0.00]	1294 [0.00]	55.85	51.72	-11.96(0)	-11.89(4)
ΔTC1Y	251	0.0000	0.005	0.140	-2.33 [0.00]	22.70 [0.00]	4286 [0.00]	105.62	31.51	-9.78(1)	-9.53(1)
ΔTC3Y	251	-0.0020	0.000	0.109	-2.88 [0.00]	24.29 [0.00]	5092 [0.00]	130.09	42.39	-9.36(1)	-8.93(13)
Handymax											
ΔTCSH	251	0.0016	0.006	0.144	-0.476 [0.00]	21.00 [0.00]	3399 [0.00]	59.26	98.79	-11.19(0)	-10.63(13)
ΔTC1Y	251	0.00155	0.004	0.102	-3.799 [0.00]	37.49 [0.00]	13043 [0.00]	111.65	23.92	-9.10(0)	-8.37(16)
ΔTC3Y	251	0.00154	0.002	0.072	-4.793 [0.00]	51.44 [0.00]	25497 [0.00]	99.69	10.21	-9.30(1)	-8.52(14)

Notes:

- ♦ All series are measured in logarithmic first differences, Δ means the first difference operator.
- ♦ N is the number of observations
- ♦ Figures in square brackets [•] indicate exact significance levels
- ♦ Skew and Kurt are the estimated centralized third and fourth moments of the data; their asymptotic distributions under the null are $T\hat{\alpha}_3'\hat{\alpha}_3/6 \sim \chi^2(1)$ and $T(\hat{\alpha}_4-3)'(\hat{\alpha}_4-3)/24 \sim \chi^2(1)$, respectively.
- ♦ Q(20) and $Q^2(20)$ are the Ljung and Box (1978) Q statistics on the first 20 lags of the sample autocorrelation function of the raw series and of the squared series; these tests are distributed as $\chi^2(20)$.The critical values are 37.57 and 31.41 for the 1% and 5% levels, respectively.
- ♦ J-B is the Jarque-Bera (1980) test for normality, distributed as $\chi^2(2)$
- ♦ ADF is the Augmented Dickey and Fuller (1981) test. The ADF regressions include none of intercept and trend terms. The lag length of the ADF test (in parentheses) is determined by minimizing the SBIC.
- ♦ PP is the Philips and Perron(1988) test; the truncation lag for the test is in parentheses.
- ♦ The 5% critical value for the ADF and PP tests is -2.869; the 1% critical value for the ADF and PP tests is -3.447.

Summary statistics of monthly rates of changes in the shipping freight market over the period of Jan 1990 to Dec 2010 in Table 4.1 show that during the sample period, the mean values of monthly spot earnings are higher than those of period rates and additionally the mean values of time charter rates seem to be lower as the period is longer. A comparison between sample standard deviations reveals that the spot earnings are more volatile than time charter rates, and time charter rates with longer duration fluctuate less. It also indicates that the Capesize variation in rates of price changes over the entire period seems to be significantly higher than that of the other two sizes.

Both the coefficients of skewness and kurtosis indicate excess skewness and kurtosis across the data. These time series tend to exhibit typical features of fat rail and spiked peak. The Jarque and Bera (1980) tests indicate departures from normality for all series. The Ljung-Box Q(20) statistics (Ljung-Box, 1978) on the first 20 lags of the sample autocorrelation function of the logarithmic series indicate the significant serial correlation for all price series. The existence of serial correlation in all series may result from the way shipbroking companies calculate the prices. An assessment by the panelist is either made on an actual fixture or, in the absence of an actual fixture, made on previous day's level, which will induce autocorrelation in different rates.

The Ljung-Box $Q^2(20)$ statistics (Ljung-Box, 1978) on the first 20 lags of the sample autocorrelation function of the log-squared series demonstrate the existence of heteroskedasticity for the returns of spot prices for three types of dry bulk vessels. Furthermore, heteroskedasticity also exists in returns of three year time-charter rates for Capesize and Panamax vessels with the exception of those of Handymax vessels. No heteroskedasticity can be found for returns of one-year time-charter rates for three ship sizes. In other words, no time-varying conditional variances can be seen for one-year time-charter rates of three ship types and for three-year time-charter rates of Handymax vessels.

We use the Augmented Dicky-Fuller (ADF,1981) and Philips-Perron (PP,1988) unit root tests on log-first differences of the price series to examine whether the series are stationary. The results show that the null hypothesis of a unit root is rejected in all series and all the returns of spot and period rates are stationary at the conventional levels for three types of vessels.

4.1.3. Empirical results of the dynamic volatility for three types of vessels

Since heteroskedasticity exists in some cases based on the summary statistics mentioned above, the simple ARIMA model is employed to investigate monthly returns with no evidence of heteroskedasticity, and the ARIMA-GARCH model is utilized to examine monthly returns with the significant evidence of heteroskedasticity. AIC and SBIC criteria have been employed to choose the lag length of the ARIMA model in the mean equation, and the Berndt, Hall, Hall and Hausman (1974) algorithm is used to estimate the GARCH specifications. Results can be seen in Table 4.2. The models seem to be well specified with the lowest SBIC and with no evidence of serial correlation and heterosckedasticity, indicated by the Ljung-Box $Q(20)$ and the Ljung-Box $Q^2(20)$ statistics (Ljung-Box, 1978). The volatility of returns has been captured by the GARCH specification.

However, variances of returns of spot prices for Capesize and Handymax vessels are not stationary, as indicated by the sum of the GARCH coefficients being 1.006 and 1.024, respectively. And variances of returns of three-year time-charter rates for Capesize and Panamax vessels are not stationary, either, indicated by the sum of the GARCH coefficients being 1.058 and 1.001, respectively. The sum of the GARCH coefficients reveals the persistence of shocks in the variance of these variables. The higher the number the more slowly old and new shocks die out. The variation of spot prices and three-year time-charter rates can be seen in Figures 4.4-4.5. It demonstrates distinctly that volatilities of price series become much more dramatic since 2003. The combination of the period before 2003 and the period after 2003 may contribute to the non-stationary GARCH process of the investigated time series. In order to investigate whether volatilities of the return series may vary significantly under different market conditions, we incorporate a dummy variable in the conditional variance of returns. The specification can be seen as follows.

$$\begin{aligned} &h_t = \omega + \alpha\varepsilon_{t-1}^2 + \beta h_{t-1} + \delta d_1 \\ &d_1 = 0 \;\; during\; 1990.1 - 2002.12;\; d_1 = 1 \;\; during\; 2003.1 - 2010.12 \end{aligned} \tag{4.3}$$

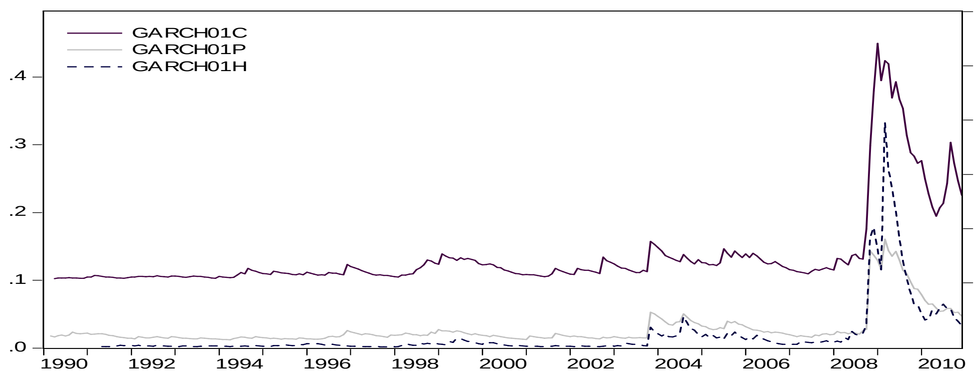

Figure 4.4: The variation of returns of spot prices for Capesize, the Panamax and the Handymax vessels

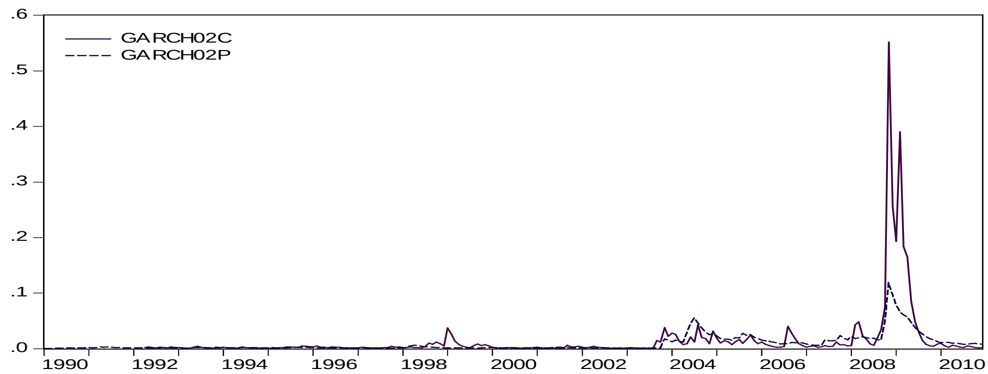

Figure 4.5: The variation of returns of three-year time-charter prices for Capesize and Panamax vessels

Table 4.3 shows the results of ARIMA/GARCH-X models under which a dummy variable is introduced in the variance in an attempt to explain the dynamics of variation of return series. Serial correlation and heteroskedasticity are not detected in all cases and values of AIC and SIC are lowered with the exception of spot rates in the Panamax, indicating these models are well specified.

A great deal of leptokurtosis and excess skewness presented in the ARIMA-GARCH model are captured by the GARCH-X specification, which can be seen by the fall in the values of normality test compared to those in Table 4.2. Persistence in variance is reduced for returns of both spot and period rates in three ship size markets, with the sum of the coefficients all falling below the unity and lower than those in Table 4.2. Thus, the inclusion of the dummy variable in the variances captures some of the volatility persistence in this common factor model.

The dummy variable is significant at the 10% significance level in the GARCH specification in most cases with the exception of spot rates for Panamax vessels. It reveals that in most cases, volatilities of spot and period prices vary significantly under different market periods for three types of dry bulk vessels, and the unconditional variance is increased over the period after 2003, compared to that during the period before 2003. This finding is accepted, because the market since 2003 becomes more volatile and more complex, leading to the dramatic volatility of prices.

Regarding volatility levels, the Capesize volatility lies above volatilities of the other two sizes, similarly the Panamax volatility is in general at a level above Handymax, but it is exceeded at several times by the hikes in the Handymax volatility during the financial crisis period in 2008 and its subsequent recovery period in 2009.

Table 4.2: Estimates of the mean and volatility of spot and period prices for dry bulk vessels (1990.1-2010.12)

Panel A: Mean estimates of various models

Capesize						Panamax						Handymax					
Spot		TC1Y		TC3Y		Spot		TC1Y		TC3Y		Spot		TC1Y		TC3Y	
φ_1	0.342** (5.864)	φ_1	0.4039** (6.732)	φ_1	0.417** (3.549)	φ_1	0.162** (2.553)	φ_1	0.518** (8.458)	φ_1	0.341** (5.694)	φ_1	0.355** (5.796)	φ_1	0.502** (9.325)	φ_1	0.585** (10.185)
		φ_8	-0.326** (-5.198)	φ_3	-0.116 (-1.337)			φ_2	-0.172** (-2.807)	φ_{13}	-0.149** (-2.936)	φ_{15}	-0.099** (-2.233)	φ_4	-0.118** (-2.189)	φ_2	-0.158** (-2.754)
		φ_9	0.3732** (5.827)					φ_7	-0.188** (-3.407)	φ_{17}	-0.153** (-3.255)	φ_{24}	0.138** (3.131)	φ_7	-0.124** (-2.296)		

Panel B: Estimates of Conditional Variances

ω	0.0007** (0.995)	ω	-	ω	0.0006* (1.752)	ω	0.001 (1.004)	ω	-	ω	0.0001* (1.712)	ω	0.0002 (1.209)	ω	-	ω	-
α_1	0.166** (2.727)	α_1	-	α_1	0.595** (2.697)	α_1	0.082 (1.643)	α_1	-	α_1	0.192** (2.718)	α_1	0.282** (2.705)	α_1	-	α_1	-
β_1	0.840** (13.954)	β_1	-	β_1	0.463** (4.562)	β_1	0.875** (10.118)	β_1	-	β_1	0.809** (13.229)	β_1	0.742** (8.923)	β_1	-	β_1	-

Panel C: Diagnostic tests on standardized residuals of models for the spot and three-year TC rates, and on residuals of models for one-year TC rates

	Capesize			Panamax			Handymax		
	Spot	TC1Y	TC3Y	Spot	TC1Y	TC3Y	Spot	TC1Y	TC3Y
J-B normality test	24.95 [0.00]	5358 [0.00]	103.79 [0.00]	1056.56 [0.00]	2840 [0.00]	628.94 [0.00]	475.98 [0.00]	19477 [0.00]	41130 [0.00]
$\bar{R}^2$	0.06	0.252	0.191	0.04	0.252	0.267	0.124	0.274	0.269
AIC	-0.747	-1.158	-2.48	-0.98	-1.313	-2.755	-2.09	-2.04	-2.832
SBIC	-0.677	-1.097	-2.40	-0.92	-1.346	-2.657	-1.98	-2.00	-2.807
Q(20)	26.09 [0.204]	25.807 [0.173]	12.31 [0.905]	23.276 [0.275]	28.63 [0.095]	13.993 [0.831]	21.93 [0.404]	30.55 [0.061]	24.280 [0.230]
$Q^2(20)$	28.473 [0.066]	6.456 [0.99]	9.798 [0.972]	4.132 [1.00]	18.158 [0.622]	9.277 [0.979]	9.63 [0.982]	3.134 [0.99]	4.179 [0.99]
Persistence ($\alpha_i + \beta_i$)	1.006	-	1.058	0.957	-	1.001	1.024	-	-

Notes: All variables are transformed in natural logarithms. ** and * indicate significance at the 5% and the 10% level, respectively.

- Figures in parentheses (.) and in squared brackets [·] indicate t-statistics and exact significance levels, respectively.
- J-B Normality is the Jarque and Bera(1980) normality test, with probability values in square brackets.
- Q(20) and $Q^2(20)$ are the Ljung and Box (1978) tests for 20th order serial correlation and heteroskedasticity in the standardized residuals and in the standardized squared residuals, respectively.
- The persistence coefficient is calculated as $\alpha_i + \beta_i$.

Table 4.3: Estimates of the ARIMA-GARCH-X model of spot and period prices for dry bulk vessels

Panel A: Mean estimates of various models

Capesize				Panamax				Handymax	
Spot		TC3Y		Spot		TC3Y		Spot	
φ_1	0.359** (5.435)	φ_1	0.459** (5.195)	φ_1	0.152** (2.393)	φ_1	0.354** (5.731)	φ_1	0.338** (5.480)
		φ_3	-0.092 (-1.058)			φ_{13}	-0.126** (-2.332)	φ_{15}	-0.104** (-2.415)
						φ_{17}	-0.147** (-2.635)	φ_{24}	0.147** (3.316)

Panel B: Estimates of conditional variances

ω	0.0020** (1.601)	ω	0.0003* (1.693)	ω	0.002 (0.819)	ω	0.0001* (2.306)	ω	0.0002 (1.469)
α_1	0.215** (3.175)	α_1	0.398** (2.049)	α_1	0.069 (1.131)	α_1	0.220** (2.134)	α_1	0.232** (2.342)
β_1	0.682* (6.253)	β_1	0.505** (3.562)	β_1	0.823** (4.546)	β_1	0.066 (0.212)	β_1	0.647** (5.355)
δ	0.007** (2.125)	δ	0.002* (1.732)	δ	0.003 (0.752)	δ	0.013** (2.105)	δ	0.003** (2.036)

Panel C: Diagnostic tests on standardized residuals

	Capesize		Panamax		Handymax
	Spot	TC3Y	Spot	TC3Y	Spot
J-B normality test	4.58 [0.10]	54.31 [0.00]	523.80 [0.00]	503.93 [0.00]	17.76 [0.00]
$\bar{R}^2$	0.064	0.191	0.04	0.261	0.119
AIC	-0.757	-2.57	-0.99	-2.83	-2.13
SIC	-0.689	-2.48	-0.91	-2.72	-2.01
Q(20)	25.175 [0.195]	11.044 [0.945]	19.740 [0.474]	11.926 [0.919]	13.237 [0.867]
$Q^2(20)$	25.537 [0.182]	10.504 [0.921]	4.132 [1.00]	6.501 [0.99]	21.349 [0.349]
Persistence ($\alpha_i + \beta_i$)	0.897	0.903	0.892	0.286	0.879

See notes to Table 4.2.

Furthermore, thinking of coefficients of α and β, regarded as the intensity of outside new and old information on market volatilities, respectively, it can be seen in Table 4.3 that the magnitude of these coefficients varies between markets. For the spot rates, β is 0.823 in the Panamax sector where old news seems to matter most, while this coefficient for the Capesize is 0.682, and falls to 0.647 for the Handymax. New shocks on the other hand seem to be the most important in the Handymax sector followed by the Capesize and the relatively small for the Panamax. This is because Capesize vessels and Panamax vessels are limited by their draught, trading cargoes and routes, they are not as flexible as Handymax vessels when responding to changes in the bulk shipping market. Handymax vessels can change their trading routes or cargoes more easily according to the market conditions. The flexibility of Handymax vessels also means the memory of volatility will not last as long as for the other two types of larger vessels.

It can be concluded that during the period before 2003, both spot and three-year time-charter rates move much more steadily and smoothly, compared to the period after 2003, when a tendency for the volatility clustering is evidently observed in the return series. That is, large changes in volatilities tend to occur around certain periods of time, which are then followed or preceded by small changes in volatility. The volatility is high during periods of large imbalances and shocks to the industry. For example, the market moves sharply during the financial crisis in 2008 and its subsequent recovery period.

Furthermore, the three markets tend to respond together to external shocks driven by some common driving forces of volatilities, but in the meantime, there are different factors to each market that make each-size ship volatility move in its own way. Thus, the volatility for Handymax and Capesize vessels has several hikes, while that for Panamax is `smoother'. This differing nature of volatilities over ship sizes is manifested in the GARCH coefficients α being higher than β for Capesize and Handymax vessels, while the opposite is true for Panamax.

The comparison of these risk levels between different size ships may be used as a guide to holding different size vessels in ship-owners' dynamic varying portfolios and can provide useful information in making better investment decisions.

4.2. Term structure and risk premium

The market risk premium is one of the most important topics in the shipping market. In general, as Adland and Cullinane(2005) point out, the levels of short-term freight rates are thought to be determined by the current supply and demand, while long-term freight rates are determined by the market's expectations about future short-term freight rates, interest rates and potentially, a risk premium. There exist a limited number of studies on investigating the risk premium in the bulk shipping market. Beenstock and Vergottis(1993) presume that the rational expectations (RE) and the efficient market hypothesis(EMH) are valid in the formation of time charter rates. The expected profitability of a time charter contract should equal the expected profitability in the spot market over the duration of the contract. However, they do not attempt to investigate the validity of RE and EMH in the formation of period rates. Veenstra(1999) presents a further investigation of the relation between spot and period freight rates for the ocean dry bulk shipping market. The present value model is used to express the period rate as expectations of future spot rates and estimated using a vector autoregressive modelling approach. It is concluded that the rational expectation hypothesis is valid for the pricing model used and it is found to be an adequately description of the relation between a spot and a corresponding period rate. The most thorough tests concerning the expectations hypothesis of the term structure come from Kavussanos and Alizadeh (2002a), who use a battery of tests to examine the validity of the expectations hypothesis in the pricing of long-term contracts for different types of dry bulk carriers, including the perfect foresight spread test, the cointegration test and the VAR model test.

The previous studies examine the risk premium irrespective of market conditions except Adland and Cullinane(2005), who argue that the risk premium in the freight market must be time-varying and depend upon the market conditions and the duration of a period time charter. However, their argument is based on maritime economic theory alone without further quantitative analysis.

This section tries to estimate the risk premium in the dry bulk ship market dependent on different market conditions by employing a market condition switching model to allow for the underlying fundamental shift in the behavior of the profit-price ratios over the estimation period during Jan 1990 to Dec 2010. The section starts with a term structure analysis in the freight market for Capesize, Panamax and Handymax vessels based on the Present Value model and the Vector Autoregressive model, proposed firstly by Campbell and Shiller(1987) and then applied in the shipping market by Kavussanus and Alizadeh (2002a). The empirical analysis indicates the failure of the efficient market hypothesis, which might be due to the existence of a risk premium. Empirical results show that the sign and the magnitude of the risk premium vary under different market conditions. The reasons behind the results are further explained in an economic way.

The section is structured as follows. Sub section 4.2.1 presents the methodology applied in the section; Sub section 4.2.2 demonstrates the data description of voyage charter and time charter rates in the shipping freight market. Sub section 4.2.3 describes empirical results as well as economic explanations regarding the risk premium under different market situations; and addresses conclusions.

4.2.1. The term structure relation

The term structure of shipping charter rates, as a hypothesis, is supposed to represent the relations between freight contracts with different duration. Such a structure explicitly indicates the difference in duration of various contracts for a given vessel. The study on the term structure relationship of shipping freight contracts is important, because uncovering the true nature of such a relationship has significant implications, which include among others: decisions on entering short- or long-term markets by comparing time charter rates with the expected spot ones; decisions on hiring in or out vessels based on the degree of mispricing; modelling freight rate movements; risk return relationships in different segments of dry bulk freight market, and the inferences about the efficient pricing of freight markets, see Kavussanos and Alizadeh (2002a). Therefore, the efficient market hypothesis of the term structure between spot and period rates has attracted much attention of researchers.

4.2.1.1. Term structure and the expectations hypothesis

A statistical model that can express the relation between the time charter rate and the voyage charter rate is a present value model. Let TC_t^T denote the TC rate at time t with T -period time charter contract and $FR_t^{T_1}$ the freight rate of spot charter contract at time t, which lasts over T_1 periods. If we assume that the Efficient Market Hypothesis (EMH) holds and a constant discount rate r, a present value model can be written as,

$$\sum_{i=0}^{n-1} \frac{TC_{t+i}^T}{(1+r)^i} = \sum_{i=0}^{n-1} \frac{E_t FR_{t+i}^{T_1}}{(1+r)^i}, \quad n = T / T_1 \tag{4.4}$$

Where $E_t FR_{t+i}^{T_1}$ is the expected voyage charter rate at time $t + i$.

After some algebraic manipulation, time charter rates can be written in terms of the expected future voyage charter rates, proposed by Kavussanos and Alizadeh(2002a),

$$TC_t^T = \theta \sum_{i=0}^{T-1} (1-\delta)\delta^i E_t FR_{t+i} \tag{4.5}$$

Where $\theta = 1/(1-\delta^T)$, the weighting factor, $\delta = 1/(1+r)$, the discount factor.

The spread between time charter and voyage charter rates, S_t is

$$S_t^{(T,T_1)} = TC_t^T - FR_t^{T_1} \tag{4.6}$$

It becomes, provided the EMH holds, the difference between a series of expected future voyage charter rates and the voyage charter rates at time,

$$S_t^{(T,T_1)} = \theta \sum_{i=0}^{T-1} (1-\delta)\delta^i E_t FR_{t+i} - FR_t^{T_1} \tag{4.7}$$

After several algebraic manipulation as described in Kavussanos and Alizadeh(2002a), we can write

$$S_t^{(T,T_1)} = \theta \sum_{i=1}^{T-1} (\delta^i - \delta^T) E_t \Delta FR_{t+i} \tag{4.8}$$

Where $S_t^{(T,T_1)} = TC^T_t - FR_t^{T_1}$ means the spread between earnings of time charter and voyage charter contracts at time t, and $E_t(\Delta FR_{t+i})$ is the future expected change in spot rates.

Equation (4.8) indicates that the spread between T -period time charter and the spot contract which lasts over T_1 periods, is equal to the weighted average of the expected future changes in spot earnings in the next n periods. To convert the expectation hypothesis of the term structure into an empirically testable form, the values of the expected future changes in the spot earnings on the right side of Equation (4.8) should be determined. The Vector Autoregressive Regression (VAR) model in Campbell and Shiller (1987, 1991) is employed in this section to forecast the future expected changes in spot earnings. Furthermore, if TC_t and FR_t are integrated series of order one, $I(1)$, then the right side of Equation (4.8) is stationary since it is a linear combination of ΔFR_t series. It implies the left side of the equation must also be stationary for the efficient market hypothesis to hold. In other words, TC_t and FR_t should be cointegrated with a cointegrating vector [1,-1]. To investigate whether TC_t and FR_t are cointegrated, cointegration test will be carried out in this section.

The VAR approach

Campbell and Shriller (1987) propose an approach of testing the efficient market hypothesis by using a bivariant VAR model, and this approach is utilized in Kavussanos and Alizadeh(2002a) to test the efficient market hypothesis in the shipping freight market. The VAR model is used to predict the future expected changes in spot rates $E_t \Delta FR_{t+i}$. It can be seen that, although logs of time charter rates and voyage charter rates might be $I(1)$, their linear combination S_t might form a stationary variable, and ΔFR_t is also stationary. Following the testing procedure of Campbell and Shiller (1987), a VAR model, consisting of a set of stationary variables S_t and ΔFR_t, can be used to make such a prediction.

$$\begin{aligned} S_t^{(T,T_1)} &= \sum_{i=1}^{p} \mu_{1,i} S_{t-i}^{(T,T_1)} + \sum_{i=1}^{p} \mu_{2,i} \Delta FR_{t-i}^{T_1} + \varepsilon_{1t} \\ \Delta FR_t^{T_1} &= \sum_{i=1}^{p} \varphi_{1,i} S_{t-i}^{(T,T_1)} + \sum_{i=1}^{p} \varphi_{2,i} \Delta FR_{t-i}^{T_1} + \varepsilon_{2t} \end{aligned} \tag{4.9}$$

Where $\mu_{j,i}$ and $\varphi_{j,i}$, j =1,2 are parameters of the VAR model. ε_{jt}, j =1,2 are error terms.

Equation (4.8) then has certain implications for this VAR system.

First, according to Equation (4.8) the spread S_t is the optimal predictor of future changes in spot rates. An increase (decrease) in the spread is due only to the market expecting future increases (decreases) in the spot rates. This has the testable implication that, if the expectations of future spot earnings are formed rationally based on more information than just current and lagged changes of spot rates, then there should be positive Granger causality from S_t to ΔFR_t, i.e. the parameter $\varphi_{1,i}$ should be significantly larger from zero.

Second, Equation (4.8) imposes a set of cross-equation restrictions on all the VAR parameters. These restrictions can be derived by the procedure as follows.

The above VAR model can be rewritten in a more compact form using companion notation as:

$$Z_t = AZ_{t-1} + v_t \tag{4.10}$$

Where $Z_t^{'} = [S_t^{(T,T_1)}, \Delta FR_t, ...S_{t-p}^{(T,T_1)}, \Delta FR_{t-p}]$ is a $(2p \times 1)$ matrix of current and lagged values of stationary variables. A is the companion form of the VAR matrix, a $(2p \times 2p)$ matrix of parameters together with zero and unit value elements, and v_t is a $(2p \times 1)$ vector of residuals and zero elements.

For all i time periods, the expected values of Z_t given the available information set H_t, will be given by:

$$E[Z_{t+i}|H_t] = A^i Z_t \quad (4.11)$$

Let $e1'$ and $e2'$ be selection vectors that pick out S_t and ΔFR_t, respectively from the vector Z_t, i.e. $e1' = [1,0,...0]$ and $e2' = [0,1,...0]$ with $2p$ elements. So $S_t = e1' Z_t$ and $\Delta FR_t = e2' Z_t$. Then VAR forecasts of future changes in spot rates can be generated as $E(\Delta FR_{t+i}|H_t) = e2' A^i Z_t$. Since S_t is contained in H_t, projecting both sides of Equation (4.8) onto H_t gives,

$$S_t^{(T,T_1)} \equiv e1' Z_t = \theta \sum_{i=1}^{n-1} (\delta^i - \delta^T) e2' A^i Z_t \quad (4.12)$$

By some mathematically manipulation, the right side of Equation (4.12) can become,

$$\theta \sum_{i=1}^{n-1} (\delta^i - \delta^T) e2' A^i Z_t = \theta\delta A e2' (I - \delta A)^{-1} (I - \delta^{n-1} A^{n-1}) Z_t - \theta\delta^n e2' (I - A)^{-1} (I - A^{n-1}) Z_t \quad (4.13)$$

For the efficient market hypothesis to hold, the following cross equation restrictions should be valid,

$$e1' = \theta\delta A e2' (I - \delta A)^{-1} (I - \delta^{n-1} A^{n-1}) - \theta\delta^n e2' (I - A)^{-1} (I - A^{n-1}) \quad (4.14)$$

A likelihood ratio test or a non-linear Wald test may be used to test the restrictions in Equation (4.14). Compared to the latter, the LR test is, however, computationally more cumbersome as it requires estimation of the VAR with the restrictions imposed. A Wald test, therefore, may be used to test the validity of those non-linear cross equation restrictions on the unrestricted VAR model. The Wald test for testing restrictions on the VAR model can be seen in Appendix C.

Campbell and Shiller (1987) suggest a specific alternative or supplementary approach to the evaluation of economic models. The idea is basically to make use of the optimal prediction property that characterizes S_t if the present value model holds. This property implies that if we estimate the parameters in the VAR model, and use these to generate an unrestricted forecast of $\theta \sum_{i=1}^{T-1} (\delta^i - \delta^T) \Delta FR_{t+i}$, then according to Equation (4.8), this forecast should be equal to S_t. Campbell and Shiller term this VAR forecast as the theoretical spread S_t', because it gives the spread that would be set in the market if the theoretical model is true. Thus, differences between the actual spread and the theoretical spread measure the deviations in the data from the present value model. From Equation (4.12), the theoretical spread S_t' is computed as,

$$S_t' = \theta \sum_{i=1}^{n-1} (\delta^i - \delta^T) e2' A^i Z_t \quad (4.15)$$

As a consequence, Campbell and Shiller (1987) suggest computing the correlation coefficient between S_t and S_t', and the ratio of their variances $\mathrm{var}(S_t)$ and $\mathrm{var}(S_t')$ in measuring the fit of the model. If there is no noise, both of these should be close to unity. Specifically, if this correlation is near unity and the variance ratio is also close to one, it must be concluded, following Campbell and Shiller (1987), that the variable in question equals its theoretical value and that the present value model holds. The empirical distributions of the correlation and the variance ratio are constructed in this section using bootstrap methods. The 90% confidence intervals for the empirical distributions are computed using 5,000 re-samples from both actual and theoretical spreads. The hypothesis of correlation equal to unity and the hypothesis of variance ratio close to unity are then tested by the empirical distributions with the 90 % confidence intervals.

Cointegration test

A set of non-stationary time series are cointegrated, if at least one linear combination of them is stationary. Cointegration means that there exists at least one long-run equilibrium relationship among variables.

Johansen (1991) procedure of testing for cointegration among variables is the most reliable approach in large samples and therefore it is preferred in this section over other less popular and powerful approaches include Engle and Granger (1987) and Engle and Yoo (1987).

If TC_t and FR_t are cointegrated, according to the Granger representation theorem, the short-term dynamics between them can always be represented by a Vector Error Correction Model (VECM).

$$\begin{aligned}\Delta TC_t &= \gamma_{1,0} + \sum_{i=1}^{p-1}\varphi_{1,i}\Delta TC_{t-i} + \sum_{i=1}^{p-1}\phi_{1,i}\Delta FR_{t-i} + w_1(TC_{t-1} + \beta_1 + \beta_2 FR_{t-1}) + \varepsilon_{1,t} \\ \Delta FR_t &= \gamma_{2,0} + \sum_{i=1}^{p-1}\varphi_{2,i}\Delta TC_{t-i} + \sum_{i=1}^{p-1}\phi_{2,i}\Delta FR_{t-i} + w_2(TC_{t-1} + \beta_1 + \beta_2 FR_{t-1}) + \varepsilon_{2,t}\end{aligned} \tag{4.16}$$

$TC_t, FR_t \sim I(1)$, ΔTC_t, $\Delta FR_t \sim I(0)$. If these two variables are cointegrated with the cointegrating vector $[1,0,-1]$, then the error correction term represents the spread, which can be regarded as a necessary condition for the EMH to hold.

Johansen(1990) proposes the following LR (Likelihood Ratio)statistic to test restrictions on parameters of cointegrating vectors:

$$-T[\ln(1-\hat{\lambda}_1^*) - \ln(1-\hat{\lambda}_1)] \sim \chi^2(2) \tag{4.17}$$

Where $\hat{\lambda}_1^*$ and $\hat{\lambda}_1$ denote the largest eigenvalues from the restricted and the unrestricted model, respectively, and T is the number of usable observations. The degree of freedom equals to the number of restrictions on β. In this section, the EMH restriction on the cointegrating vector is rejected by the empirical tests for three sizes of dry bulk carriers with contracts of different duration.

4.2.1.2. The market dependent and time-varying risk premium

The risk premium is tied with the expectations theory of the term structure. In the freight market, a positive risk premium implies that the period time charter rate exceeds the expected TCE spot freight rate from voyage chartering during the same time period and vice versa. The previous research has tested the validity of the expectations theory in the freight market together with the risk premium. Veenstra(1999) postulates that shipowners prefer voyage charters and require a (constant) positive risk premium to enter into period time charters to offset the loss in liquidity. This liquidity premium hypothesis is rejected by the empirical tests. Kavussanos and Alizadeh(2002a) attribute the failure of the expectations hypothesis to the existence of a time-varying risk premium and attempt to model it using an EGARCH-M approach. Adland(2004) suggests that the risk premium in the freight market in bulk shipping must be time varying. The section discusses in detail the risk premium depending on the state of the spot freight market and the duration of the period charter in a systematic way and taking into account the risk types and the agents' perception of risk.

The possible failure of EMH is mainly attributed to the existence of risk premium, see for example, Engle et al (1987), Engle and Ng (1993a), Hurn et al(1995), and Kavussanos and Alizadeh (2002a) among others. The expectation theory postulates that long-term time-charter rates should be determined by the expected future freight rates and interest rates, and potentially a risk premium. The expected excess returns from operating in time charter market and spot market, are then given by:

$$R_t = TC_t^T - \theta\sum_{i=0}^{T-1}(1-\delta)\delta^i E_t FR_{t+i} \tag{4.18}$$

$$TC_t^T = \theta\sum_{i=0}^{T-1}(1-\delta)\delta^i E_t FR_{t+i} + \lambda_t + \eta_t \tag{4.19}$$

Where λ_t is the implied risk premium, η_t is the error term. R_t is the expected excess return.

The expected returns are derived based on the past information and serial correlation might exist for residual series. If heteroskedasticity exists for the error terms, a GARCH-M model, therefore, can be utilized to model the expected returns. To investigate the possibility that the risk premium in the freight market may vary under different market conditions, a GARCH-M is extended to the market condition switching regression model:

$$\begin{gathered} R_t = \lambda_s(d_{s,t}\sigma_t) + \lambda_w(d_{w,t}\sigma_t) + \eta_t,\ \ \eta_t = \sum_{i=1}^{n}\kappa_i\varepsilon_{t-i} \\ \sigma_t^2 = \omega + \alpha\varepsilon_{t-1}^2 + \beta\sigma_{t-1}^2,\ \varepsilon_t = \sigma_t z_t,\ z_t \sim iid(0,1) \\ d_{s,t} = 1\ and\ d_{w,t} = 0\ if\ FR_t - 1/12\sum_{i=0}^{11} FR_{t-i} > 0\ \ Strong\ Freight\ Market \\ d_{w,t} = 1\ and\ d_{s,t} = 0\ if\ FR_t - 1/12\sum_{i=0}^{11} FR_{t-i} \le 0\ \ Weak\ Freight\ Market \end{gathered} \tag{4.20}$$

Where ε_t is the error term with the expected mean of zero and a specified distributed time-varying variance. σ_t^2 is the conditional variance. $d_{s,t}$ and $d_{w,t}$ are state dummies. ϕ_s and ϕ_w are parameters.

If no heteroskedasticity is found for error terms, the expected excess returns can be modeled as,

$$\begin{gathered} R_t = \lambda_s(d_{s,t}\phi_1) + \lambda_w(d_{w,t}\phi_2) + \eta_t \\ \eta_t = \sum_{i=1}^{n}\kappa_i\varepsilon_{t-i},\ \varepsilon_t = \sigma z_t,\ z_t \sim iid(0,1) \end{gathered} \tag{4.21}$$

Where ε_t is the error term with the expected mean of zero and a specified distributed unconditional variance σ^2. $d_{s.t}$ and $d_{w.t}$ are state dummies. ϕ_s and ϕ_w are parameters.

4.2.2. Description of data and statistical properties

In order to study the term structure relation in the freight market, comparable voyage charter rates and time charter rates are utilized. Monthly spot earnings on daily basis for the transatlantic round voyage, which are the time-charter equivalents of voyage charter rates, are used in this section for the term structure study.

The data set used consists of monthly time charter rates and spot earnings for dry bulk vessels, namely Handymax vessels of 45,000 DWT and Panamax vessels of 65,000 DWT covering the period from Jan 1990 to Dec 2010, yielding a sample of 252 observations. Monthly time charter rates and spot earnings for Capesize vessels of 150,000 DWT are collected over the period from Dec 1991 to Dec 2010, yielding a sample of 229 observations. Monthly one-year and three-year time charter rates, together with spot earnings are all obtained from Clarkson Research Studies (2010). Spot earnings in this section refer to the Time Charter Equivalents, abbreviated as TCEs of spot rates. They are defined as the revenues minus voyage costs from spot market operations. The trends of all these variables can also been seen in Figures 4.1-4.3 in Section 4.1. It's clearly revealed that prices have changed dramatically and the trends are distinctly different after 2003, compared with the period before 2003, which may create structural breaks in the series during the whole period. Summary statistics of logarithmic daily time charter rates and spot earnings during the sample period are presented in Table 4.4.

Results of all price series in Table 4.4 show that during the sample period, the mean values of spot earnings per day are higher than time charter rates, and additionally the mean values of time charter rates seem to be lower when the duration is longer. A comparison between sample standard deviations reveals that the spot earnings are more volatile than time charter rates, and time charter rates with long duration fluctuate less than time charter rates with short duration.

Table 4.4: Descriptive statistics of logarithmic timecharter rates and spot earnings

	N	Mean	Median	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Q(20)	$Q^2(20)$	ADF(lags)	PP	ADF(lags)	PP
										Lev	Lev	1st diffs	1st diffs
Capesize: (1991:12-2010:12)													
Lspot	229	10.034	9.878	0.775	0.625[0.00]	2.691[0.34]	15.69[0.00]	1798.2	1834.8	-2.66(2)	-2.58(8)	-12.09(1)	-11.40(22)
Ltc1y	229	9.987	9.763	0.681	1.007[0.00]	3.269[0.41]	39.03[0.00]	2114.3	2077.9	-2.46(9)	-1.69(0)	-4.75(9)	-9.89(12)
Ltc3y	229	9.923	9.806	0.519	1.363[0.00]	4.513[0.00]	91.97[0.00]	1848.9	1818.4	-2.08(3)	-2.34(3)	-9.70(2)	-8.96(17)
Spread1y	229	-0.047	-0.059	0.204	0.908[0.00]	7.082[0.00]	188.83[0.00]	314.1	73.39	-5.75(0)	-5.66(3)	--	--
Spread3y	229	-0.111	-0.132	0.368	0.084[0.60]	2.739[0.42]	0.910[0.63]	859.1	239.85	-3.99(0)	-3.87(7)	--	--
Panamax: Sample Period (1990:01-2010:12)													
Lspot	252	9.406	9.284	0.644	0.760[0.00]	3.126[0.74]	24.258[0.00]	1421	1455.3	-3.40(3)	-2.95(5)	-7.40(2)	-14.12(3)
Ltc1y	252	9.396	9.265	0.543	1.401[0.00]	5.007[0.00]	123.78[0.00]	1395.5	1377.3	-3.41(1)	-2.80(5)	-9.76(1)	-9.53(3
Ltc3y	252	9.266	9.223	0.405	1.666[0.00]	6.420[0.00]	237.44[0.00]	1174.7	1170.8	-350(1)	-2.85(3)	-9.45(1)	-9.06(12)
Spread1y	252	-0.010	0.009	0.218	0.337[0.03]	5.634[0.00]	77.01[0.00]	601.69	159.44	-3.68(2)	-5.42(5)	--	--
Spread3y	252	-0.139	-0.066	0.407	-0.379[0.01]	2.539[0.13]	8.200[0.02]	1480.6	772.18	-3.25(0)	-3.17(4)	--	--
Handymax: Sample Period (1990:01-2010:12)													
Lspot	252	9.416	9.204	0.575	0.943[0.00]	3.110[0.74]	37.175[0.00]	2100.8	2099.1	-2.86(1)	-2.42(4)	-13.73(0)	-13.638
Ltc1y	252	9.386	9.179	0.542	1.218[0.00]	3.668[0.00]	66.478[0.00]	2366.9	2315.4	-2.58(1)	-1.99(3)	-9.56(1)	-8.72
Ltc3y	252	9.319	9.213	0.388	1.514[0.00]	4.957[0.00]	135.39[0.00]	2344.6	2299	-2.54(1)	-1.96(4)	-9.14(0)	-8.67
Spread1y	252	-0.030	-0.031	0.115	2.205[0.00]	15.664[0.00]	1873.3[0.00]	261.5	158.52	-6.69(1)	-5.54(9)	--	--
Spread3y	252	-0.097	-0.031	0.249	-0.047[0.76]	4.240[0.00]	16.106[0.00]	1354	926.6	-3.91(1)	-3.18(9)	--	--

Notes:

- Lspot means logarithmic spot earnings; Ltc1y means logarithmic 1-year timecharter rates; Ltc3y means logarithmic 3-year timecharter rates; Spread1y means logarithmic difference between 1-year timecharter rates and spot earnings; Spread3y means logarithmic difference between 3-year timecharter rates and spot earnings
- N is the number of observations Figures in square brackets [·] indicate exact significance levels
- Skew and Kurt are the estimated centralized third and fourth moments of the data; their asymptotic distributions under the null are $T\hat{\alpha}_3'\hat{\alpha}_3/6\sim\chi^2(1)$ and $T(\hat{\alpha}_4-3)'(\hat{\alpha}_4-3)/24\sim\chi^2(1)$ respectively.
- Q(20) and $Q^2(20)$ are the Ljung and Box (1978) Q statistics on the first 20 lags of the sample autocorrelation function of the raw series and of the squared series; these tests are distributed as $\chi^2(20)$.The critical values are 58.11 and 51.48 for the 1% and 5% levels, respectively.
- J-B is the Jarque-Bera (1980) test for normality, distributed as $\chi^2(2)$.
- ADF is the Augmented Dickey and Fuller (1981) test. The ADF regression includes an intercept term and no trend term. The lag length of the ADF test (in parentheses) is determined by minimizing the SBIC, and the unit root test includes no constant and no trend term.
- PP is the Philips and Perron(1988) test; the truncation lag for the test is in parentheses.
- Lev and 1st diffs refer to price series in log-levels and log-first differences, respectively.
- The 1% critical value for the ADF and PP tests is -3.46; The 5% critical value for the ADF and PP tests is -2.87.

Excess skewness and kurtosis are shown in all price series, except for spot rates, which do not exhibit significant kurtosis. Data with excess kurtosis tend to have a distinct peak near the mean and drop quickly. The Jarque and Bera (1980) tests indicate departures from normality for all series. The Ljung-Box Q(20) and $Q^2(20)$ statistics (Ljung-Box, 1978) on the first 20 lags of the sample autocorrelation function of the logarithmic first difference series and of the squared series indicate significant serial correlation and the existence of heteroskedasticity, respectively. The existence of serial correlation in all series may result from the way ship-broking companies calculate the prices. As mentioned above, an assessment by the panelist is either made on an actual fixture or, in the absence of an actual fixture, made on previous day's level, which will induce autocorrelation in different rates.

We use the Augmented Dicky-Fuller (ADF,1981) and Philips-Perron (PP,1988) unit root tests on the log levels and log-first differences of the price series to examine whether the series are stationary. The results show that all variables are non-stationary on log-levels and stationary on log first differences.

For the spread between spot and one-year time charter rates, results reveal that there seem to be significant excess skewness and kurtosis and the J-B statistics reject the hypothesis of normality (skewness=0, kurtosis=3) in all cases. For the spread between spot and three year time charter rates, excess skewness is only observed for the spread series in the Panamax market, and excess kurtosis is found for the spread series in the Capesize and Handymax markets. The Ljung-Box Q(20) and $Q^2(20)$ statistics reject the null hypothesis of non-autocorrelation and non heteroskedasticity in all price series. The augmented Dicey-Fuller and Philips Perron unit root tests display that all variables are stationary at levels at the 5% significance level.

4.2.3. Empirical results

The results from testing the efficient market hypothesis and the time-varying risk premium under different market conditions are presented in this section. Firstly, the efficient market hypothesis is tested by the VAR approach and cointegration test. Cointegrating relationships between spot and time charter rates are investigated. If such relationships exist between variables, restrictions implied by the EMH are imposed on the cointegrating vector to test the hypothesis. Secondly, a GARCH-M model is used to estimate the risk premium between current time charter rates and their expected future spot earnings, which can be derived from a VAR model. The constant discount rate used to get the expected future spot earnings is set to 5.7%, which is the mean value of 6-month LIBOR rate during the sample period. Finally, the implications of the risk premium in the spot freight market are future explained.

4.2.3.1. Testing the efficient market hypothesis

As discussed in the sub-section 4.2.1, two approaches are utilized in this section, namely the VAR model and the cointegration test, to test the efficient market hypothesis.

The VAR model

Following Campbell and Shiller (1987), a bi-variant VAR model is constructed in order to utilize the information in the spread series for forecasting future changes in spot earnings needed in Equation (4.9). The general VAR model of Equation (4.9) is estimated for one-year and three-year rates for the Capesize, Panamax and Handymax markets. Since we use average monthly spot rates, the duration for a trip-charter is assumed to be one month. Thus, T_1 in Equation (4.4) is assumed to be 1, and T is assumed to be 12 for a one-year time charter contract, or 36 for a three-year time charter contract. The standard errors of the estimated parameters are corrected for serial correlation and/or heteroskedasticity using the Newey-West (1987) method. The lag length in each model is selected using the Schwarz Information Criterion. Results are in Table 4.5.

Table 4.5: Estimates of VAR models for three ship size markets

$$\begin{pmatrix}\Delta Spread_t\\ \Delta Spot_t\end{pmatrix} = \sum_{i=1}^{p}\begin{pmatrix}\theta_{1,i} & \gamma_{1,i}\\ \theta_{2,i} & \gamma_{2,i}\end{pmatrix}\begin{pmatrix}\Delta Spread_{t-i}\\ \Delta Spot_{t-i}\end{pmatrix} + \begin{pmatrix}c_{1,t}\\ c_{2,t}\end{pmatrix} + \begin{pmatrix}\varepsilon_{1,t}\\ \varepsilon_{2,t}\end{pmatrix},\ \begin{pmatrix}\varepsilon_{1,t}\\ \varepsilon_{2,t}\end{pmatrix} \sim iid(0,\Sigma)$$

Panel A: VECM model estimates

	Capesize				Panamax				Handymax			
	$\Delta Spread_t^{1y}$	$\Delta Spot_t$	$\Delta Spread_t^{3y}$	$\Delta Spot_t$	$\Delta Spread_t^{1y}$	$\Delta Spot_t$	$\Delta Spread_t^{3y}$	$\Delta Spot_t$	$\Delta Spread_t^{1y}$	$\Delta Spot_t$	$\Delta Spread_t^{3y}$	$\Delta Spot_t$
$\theta_{j,1}\ j=1,2$	0.168	0.984**	0.164	1.024**	0.844**	0.709**	0.852**	0.777*	0.539**	1.066**	0.410*	1.242**
	(0.788)	(2.659)	(0.776)	(3.66)	(3.25)	(3.81)	(3.112)	(1.94)	(2.673)	(3.199)	(1.834)	(5.997)
$\theta_{j,2}\ j=1,2$	0.549**	-0.737**	0.726**	-0.928**	-0.490*	-0.403	-0.305	-0.553	0.052	-0.762**	0.213	-1.084**
	(2.831)	(-2.34)	(3.537)	(-3.503)	(-1.878)	(-1.395)	(-0.763)	(-1.035)	(0.394)	(-4.789)	(0.726)	(-3.572)
$\theta_{j,3}\ j=1,2$					0.437**	-0.165	0.356	-0.140			0.022	0.062
					(3.062)	(-0.673)	(1.442)	(-0.527)			(0.076)	(0.165)
$\theta_{j,4}\ j=1,2$											0.260	-0.132
											(1.179)	(-0.443)
$\gamma_{j,1}\ j=1,2$	-0.462**	0.807**	-0.670**	1.070**	0.071	0.464**	-0.065	0.624*	-0.238**	0.758**	-0.496**	1.087**
	(-3.55)	(3.732)	(-4.035)	(4.265)	(0.542)	(4.743)	(-0.321)	(1.952)	(-2.609)	(6.286)	(-2.942)	(7.010)
$\gamma_{j,2}\ j=1,2$	0.146**	-0.248**	0.330**	-0.384**	-0.185	-0.055	-0.166	-0.016	-0.094	0.033	-0.180	0.039
	(2.42)	(-3.487)	(3.576)	(-3.619)	(-1.564)	(-0.332)	(-0.808)	(-0.073)	(-1.029)	(0.261)	(-1.268)	(0.215)
$\gamma_{j,2}\ j=1,2$					-0.087	0.182*	-0.159	0.201**			-0.170	0.104
					(-1.097)	(1.941)	(-1.409)	(1.998)			(-1.081)	(0.449)
$\gamma_{j,2}\ j=1,2$											0.202*	-0.212
											(1.744)	(-1.503)
$c_j\ j=1,2$	-0.015	0.014	-0.015	0.013			-0.015	0.013	-0.011	0.009	-0.008	0.009
	(-1.597)	(0.873)	(-1.302)	(0.934)			(-1.342)	(1.003)	(-2.47)	(1.132)	(-1.299)	(1.102)
Causality test												
$\Delta Spread_t \rightarrow \Delta Spot_t$	9.648	[0.00]	14.33	[0.00]	16.775	[0.00]	6.17	[0.09]	23.43	[0.00]	37.31	[0.00]
$\Delta Spot_t \rightarrow \Delta Spread_t$	17.238	[0.00]	24.91	[0.00]	3.692	[0.297]	3.743	[0.29]	9.14	[0.01]	19.83	[0.00]

Table 4.5: Continued

Wald statistics	$\chi^2(4)$	59.77 [0.00]	$\chi^2(4)$	120.75 [0.00]	$\chi^2(6)$	140.85 [0.00]	$\chi^2(6)$	96.34 [0.00]	$\chi^2(4)$	32.117 [0.00]	$\chi^2(8)$	86.07 [0.00]
$\frac{Var(Spread)}{Var(Spread^*)}$	2.394	{0.00}	2.353	{0.00}	4.102	{0.00}	3.931	{0.00}	1.666	{0.073}	2.724	{0.00}
$cor(Spread, Spread^*)$	0.847	{0.00}	0.935	{0.00}	0.131	{0.00}	0.829	{0.00}	0.863	{0.00}	0.905	{0.00}
Panel B: residual diagnostics												
J-B test	60.85 [0.00]	5822 [0.00]	138.83 [0.00]	52.53 [0.00]	948.02 [0.00]	1244 [0.00]	284.45 [0.00]	532.11 [0.00]	725.05 [0.00]	3393 [0.00]	1126.55 [0.00]	1647.8 [0.00]
$Q(20)$	17.157 [0.643]	37.21 [0.04]	37.56 [0.056]	45.346 [0.00]	18.147 [0.578]	41.637 [0.00]	15.967 [0.719]	26.409 [0.153]	28.23 [0.104]	45.87 [0.125]	16.21 [0.703]	20.547 [0.425]
$Q^2(20)$	164.79 [0.00]	119.73 [0.00]	137.97 [0.00]	245.90 [0.00]	43.107 [0.00]	49.904 [0.00]	189.59 [0.00]	103.84 [0.00]	75.25 [0.00]	67.32 [0.00]	74.08 [0.00]	84.50 [0.00]
$\overline{R^2}$	0.644	0.245	0.797	0.279	0.654	0.169	0.857	0.177	0.656	0.286	0.89	0.347

Notes:
- All variables are transformed in natural logarithms
- ** and * indicate significance at the 5% and 10% levels, respectively
- Figures in parentheses (.) and in squared brackets [·] indicate t-statistics and exact significance levels, respectively
- J-B Normality is the Jarque and Bera(1980) normality test, with probability values in square brackets
- $Q(20)$ and $Q^2(20)$ are the Ljung and Box (1978) tests for 20th order serial correlation and heteroskedasticity in the standardized residuals and in the standardized squared residuals, respectively.
- ARCH(20) is the Engle's(1982) F test for Autoregressive Conditional Heteroskedasticity.
- The critical values of $\chi^2(4)$, $\chi^2(6)$ and $\chi^2(8)$at the 5% significant level are 9.48, 12.59 and 15.51, respectively.
- {} means the probability values of accepting the hypothesis of variance ratio equal to unity and correlation equal to unity.

Granger causality tests reported in Table 4.5 indicate significant causality from the spread $\Delta Spread_t$ to spot rates $\Delta Spot_t$ in all cases. Also, there seem to be some feedback effects from $\Delta Spot_t$ to $\Delta Spread_t$, with the exceptions of two pairs in the Panamax market. Such a pattern in Granger causality tests implies that the spread between spot and time charter rates contains information of predicting future changes in spot market earnings. The interpretation of this causal relationship is that when the spread widens, either earnings from spot operations, or earnings from the period market operations, will move in the next period in a direction that reduces this divergence and brings back the system to its long-run equilibrium.

Table 4.5 also contains Wald test results of imposing the non-linear restrictions of Equation (4.14), implied by the EMH on the VAR model of Equation (4.9). The EMH is rejected at the 5% level in all cases, the exception being the pair of one year time-charter rates and spot earnings in the Handymax.

Results from correlation coefficients and variance ratio tests are displayed in Table 4.5 as well. Simulated estimates of the variance of the actual spread over that of the theoretical spread, together with correlations are shown in each case. Results show that correlations between the actual and the theoretical spread are not very high. Bootstrap simulation of the ratios in all markets reveals that the variance ratios of the actual spread over the theoretical spread can be far from the unity at the conventional significance levels in all cases. Thus, the actual spread series show excess volatility over the theoretical spread series, a result that is not consistent with the EMH.

Cointegration tests

Having identified that price series in both the spot market and the period market are all $I(1)$ variables, the Johansen (1988) procedure is employed in order to test for cointegration between variables. There are two pairs in each market, namely the pair of one-year time-charter rates and spot earnings, as well as the pair of three-year time-charter rates and spot earnings. The Schwartz Bayesian Information Criterion (1978), Akaike Information Criterion (AIC) (Akaike, 1973) and Likelihood ratio test are used to determine the lag length in the Vector Error Correction Model (VECM). The results for cointegration tests can be clearly seen in Table 4.6.

Results in Table 4.6 reveal that $\lambda_{\max}$ and λ_{trace} statistics reject the null hypothesis of no cointegrating vector at the significant levels in almost all cases with the exception of the pair of three-year time charter rates and spot earnings in the Capesize market. For this pair, the null hypothesis of no cointegrating vector cannot be rejected at the 5% significance level.

The efficient hypothesis is examined next by testing the restrictions $(1, 0, -1)$ in the cointegrating vector $(1, \beta_1, \beta_2)$. If these restrictions hold at the conventional significant levels, then the EMH is supported. Results in Table 4.7 indicate that the restrictions imposed on the cointegrating vector are all rejected by Johansen and Juselius (1990) test at the 5% significant level.

To investigate the short-run properties of spot and time charter rats, we examine the estimated error correction coefficients α_1 and α_2. Results in Table 4.7 reveal that the evidence of α_1 and α_2 being statistically significant with opposite signs cannot be detected in the markets.

In the Capesize market, the estimated error correction coefficient of time charter rates α_1 is insignificant, whereas that of spot prices, α_2 is statistically positive. This implies the past forecast errors affect the current spot rates, but not the time-charter rates. In other words, spot rates respond to the previous deviations from the long-run equilibrium relationship and do all the correction to eliminate the disequilibrium.

Table 4.6: Johansen (1988) tests for the number of cointegrating vectors between spot and period prices

	Lags	*Hypothesis (maximal)*		*Test statistic*	*Hypothesis (trace)*		*Test statistic*	95% Critical values	
		H_0	H_1	$\lambda_{\max}$	H_0	H_1	λ_{trace}	$\lambda_{\max}$	λ_{trace}
Capesize									
Tc1y/Spotc	1,8,9	$r=0$	$r=1$	59.48	$r=0$	$r=1$	64.97	15.89	20.26
		$r\le 1$	$r=2$	5.48	$r\le 1$	$r=2$	5.48	9.16	9.16
Tc3y/Spotc	2, 8	$r=0$	$r=1$	12.55	$r=0$	$r=1$	17.85	15.89	20.26
		$r\le 1$	$r=2$	5.29	$r\le 1$	$r=2$	5.29	9.16	9.16
Panamax									
Tc1y/Spotp	5	$r=0$	$r=1$	39.50	$r=0$	$r=1$	47.12	15.89	20.26
		$r\le 1$	$r=2$	7.62	$r\le 1$	$r=2$	7.62	9.16	9.16
Tc3y/Spotp	2,5	$r=0$	$r=1$	17.26	$r=0$	$r=1$	24.04	15.89	20.26
		$r\le 1$	$r=2$	6.78	$r\le 1$	$r=2$	6.78	9.16	9.16
Handymax									
Tc1y/Spoth	1,4	$r=0$	$r=1$	37.50	$r=0$	$r=1$	41.13	15.89	20.26
		$r\le 1$	$r=2$	3.63	$r\le 1$	$r=2$	3.63	9.16	9.16
Tc3y/Spoth	1,4	$r=0$	$r=1$	16.57	$r=0$	$r=1$	20.70	15.89	20.26
		$r\le 1$	$r=2$	2.65	$r\le 1$	$r=2$	2.65	9.16	9.16

Notes:

- Lags is the lag length of a VAR model; the lag length is determined using the SBIC(1978)
- r represents the number of cointegrating vectors
- ** refers to one cointegration vector at the 10% significance level
- $\lambda_{\max}(r,r+1) = -T\ln(1-\hat{\lambda}_{r+1})$ and $\lambda_{trace}(r) = -T\sum_{i=r+1}^{n}\ln(1-\hat{\lambda}_i)$ where $\hat{\lambda}_i$ are the estimated eigenvalues of the $\prod$ matrix in Eq.(1). Critical values are from Osterwald-Lenum(1992), Table1.

Table 4.7: Model specifications and tests of unbiasedness for the time-charter and spot rates

$$\begin{pmatrix}\Delta TC_t\\ \Delta Spot_t\end{pmatrix} = \sum_{i=1}^{p}\Gamma_i\begin{pmatrix}\Delta TC_{t-i}\\ \Delta Spot_{t-i}\end{pmatrix} + \begin{pmatrix}\alpha_1\\ \alpha_2\end{pmatrix}\begin{pmatrix}1 & \beta_1 & \beta_2\end{pmatrix}\begin{pmatrix}TC_{t-1}\\ 1\\ Spot_{t-1}\end{pmatrix} + \begin{pmatrix}\varepsilon_{1,t}\\ \varepsilon_{2,t}\end{pmatrix}, \begin{pmatrix}\varepsilon_{1,t}\\ \varepsilon_{2,t}\end{pmatrix} \sim iid(0,\Sigma)$$

Routes	Lags	Coefficients Estimates		Hypothesis Tests on β'		Granger Causality Test	
		α_1	α_2	$\beta' = (1\ \beta_1\ \beta_2)$	$H_1: \beta' = (1,0,-1)$	$\Delta TC_t \rightarrow \Delta Spot_t$	$\Delta Spot_t \rightarrow \Delta TC_t$
Capesize							
Tc1y/Spotc	1,8,9	0.022 (0.418)	0.423** (5.06)	(1,-0.13,-0.98)	9.58 [0.00]	25.56 [0.00]	11.31 [0.01]
Panamax							
Tc1y/Spotp	5	-0.187** (-3.72)	0.067 (0.818)	(1,-0.84,-1.53)	9.06 [0.01]	9.97 [0.04]	29.86 [0.00]
Tc3y/Spotp	2,5	-0.097** (-4.138)	-0.138** (-2.80)	(1,-6.18,-0.33)	11.37 [0.00]	9.16 [0.03]	5.11 [0.16]
Handymax							
Tc1y/Spoth	1,4	-0.224** (-3.482)	0.022 (0.258)	(1,-0.952,-0.43)	6.220 [0.045]	25.06 [0.00]	17.44 [0.00]
Tc3y/Spoth	1,3	-0.118** (-3.678)	-0.066 (-1.141)	(1,-0.622,-3.47)	12.53 [0.00]	32.07 [0.00]	10.68 [0.00]

Notes:

- α_1 and α_2 are the coefficient estimates of the error correction model implied by the normalised cointegrating parameters, *t*-statistics for the null hypothesis ($\alpha_1 = 0$) are in parentheses (.).
- Estimates of the coefficients in the cointegrating vector are normalised with respect to the coefficient of the spot rate.
- The statistic for the unbiasedness hypothesis tests on the coefficients of the cointegrating vector is $-T[\ln(1-\hat{\lambda}_1^*)-\ln(1-\hat{\lambda}_1)]$ where $\hat{\lambda}_1^*$ and $\hat{\lambda}_1$ denote the largest eigenvalues of the restricted and the unrestricted models, respectively. The statistic is distributed as χ^2 with degrees of freedom equal to the number of restrictions placed on the cointegrating vector.
- The null hypothesis for $\Delta TC_t \rightarrow \Delta Spot_t$ is ΔTC_t does not Granger cause $\Delta Spot_t$; the null hypothesis for $\Delta Spot_t \rightarrow \Delta TC_t$ is $\Delta Spot_t$ does not Granger cause ΔTC_t .
- Granger Causality tests areWald statistics distributed as $\chi^2(r)$, where r is the number of the restricted parameters. This is equal to the number of lags, p, included in the model.
- Exact significance levels are in square brackets [.].

Turning to the Panamax and Handymax markets. For the pair of spot and one-year time charter rates, α_1 is negative and significant at the 5% level, whereas α_2 is insignificant. This indicates that only the time charter rates respond to the previous deviations from the long-run equilibrium relationship and do all the correction to eliminate the disequilibrium. For the pair of spot and three-year time charter rates, both α_1 and α_2 are negative. The negative signs of both error correction coefficients indicate that a negative forecast error at period $t-1$ will force both the spot and time-charter rates to decrease. Hence any disequilibrium at period $t-1$ is also carried forward to period t .

The rejection of restrictions on the cointegrating vector and the findings of error correction coefficients might result from the existence of risk premium, which speculators are willing to offer to balance between the period and the spot markets.

4.2.3.2. Modelling the market dependent time-varying risk premium

Overall, the results of various tests reject the efficient market hypothesis. The rejection might be due to the existence of the risk premium, which may also be time-varying. The expected excess returns achieved between spot and period rates can be modelled depending on the existence of heteroskedasticity for the error terms. Additionally, in order to investigate the possibility that the risk premium in the freight market may vary under different market conditions, dummies of strong market conditions and weak market conditions are applied into models. If current spot price at period t is below or equal to the mean of prices in the past 12 months, the market condition at period t is regarded as weak, otherwise, it is strong.

Variance tests indicate that there exists heteroskedasticity for the expected excess returns of Capesize and Panamax, while there is no heteroskedasticity for the Handymax. The system of Equations (4.20) is used to model the possible risk premium for the Capesize and Panamax, and the system of Equations (4.21) is for the Handymax. Results are demonstrated in Table 4.8 for three markets. The order of the Moving Average terms is set to 12, since it is found to be enough to capture the serial correlation. Diagnostic tests confirm that all models are well specified.

Results reveal that during the sample period, there exists a risk premium in all ship size markets. Signs and types of the risk premium, however, may be dependent on the market periods and on different ship size.

In the Capsize market, the risk premium is found to be time-varying. The parameters of the standard deviation terms in the mean equation are observed to be statistically significant and negative for two pairs, indicating the existence of negative time-varying risk premiums during the market upturns. These coefficients can be interpreted as the elasticity of the expected excess returns with respect to the standard deviation of forecast errors. While during the market downturns, coefficients of standard deviation terms are not significant at the conventional levels.

In the Panamax market, the coefficient of the lagged standard error terms are found to be statistically significant and negative for the pair between spot and three year time charter rates, while the parameter is found to be negative, but not statistically significant in a strong freight market. In a weak freight market, the coefficients of the lagged standard error terms are observed to be positive, but only statistically significant for the pair between spot and one-year time charter rates.

In the Handymax market, the risk premium is found to be constant for two pairs. The coefficients of the constant term can be seen to be statistically significant and negative in a strong freight market, while the parameters of the constant term are found to be insignificant at the conventional levels in a weak freight market.

Table 4.8: Estimates of models for excess returns of time-charter rates over spot rates in different markets (1990.1-2010.12)

$$R_t = \lambda_s(d_{s,t}\sigma_t) + \lambda_w(d_{w,t}\sigma_t) + \eta_t, \quad \eta_t = \sum_{i=1}^{n} \kappa_i \varepsilon_{t-i}$$

$$\sigma_t^2 = \omega + \alpha\varepsilon_{t-1}^2 + \beta\sigma_{t-1}^2, \ \varepsilon_t = \sigma_t z_t, \ z_t \sim iid(0,1)$$

$$R_t = \lambda_s(d_{s,t}\phi_1) + \lambda_w(d_{w,t}\phi_1) + \eta_t$$

$$\eta_t = \sum_{i=1}^{n} \kappa_i \varepsilon_{t-i}, \ \varepsilon_t = \sigma z_t, \ z_t \sim iid(0,1)$$

Panel A: Conditional mean estimates

Capesize				Panamax				Handymax			
1y/spot		3y/spot		1y/spot		3y/spot		1y/spot		3y/spot	
λ_s	-0.588** (-2.99)	λ_s	-0.549** (-2.21)	λ_s	-0.331 (-1.35)	λ_s	-0.648** (-2.35)	λ_s	-0.048** (-2.15)	λ_s	-0.064** (-3.03)
λ_w	0.313 (1.58)	λ_w	0.150 (0.62)	λ_w	0.504** (2.07)	λ_w	0.406 (1.46)	λ_w	-0.003 (-0.126)	λ_w	-0.016 (-0.787)
κ_1	0.381** (5.22)	κ_1	0.441** (5.96)	κ_1	0.711** (10.41)	κ_1	0.742** (11.31)	κ_1	0.738** (11.61)	κ_1	0.616** (9.50)
κ_2	0.338** (4.486)	κ_2	0.396** (5.03)	κ_2	0.408** (5.228)	κ_2	0.494** (6.85)	κ_2	0.664** (8.44)	κ_2	0.394** (5.567)
κ_3	0.395** (5.08)	κ_3	0.433** (5.06)	κ_3	0.485** (6.38)	κ_3	0.366** (4.81)	κ_3	0.582** (6.50)	κ_3	0.440** (6.28)
κ_4	0.276** (3.23)	κ_4	0.363** (4.32)	κ_4	0.246** (3.24)	κ_4	0.223** (2.99)	κ_4	0.171* (1.91)	κ_4	0.196** (3.07)
κ_5	0.249** (3.09)	κ_5	0.394** (5.08)	κ_5	0.074 (1.00)	κ_5	0.158** (2.13)	κ_5	0.190** (2.39)	κ_5	
κ_6	0.135* (1.656)	κ_6	0.245** (3.20)	κ_6	0.213** (2.98)	κ_6	0.265** (4.359)	κ_6	0.222** (3.47)	κ_6	0.156** (2.38)
κ_7	0.147** (2.09)	κ_7	0.250** (3.98)	κ_7	0.264** (3.94)	κ_7	0.236** (3.82)	κ_7	-	κ_7	0.181** (2.44)
κ_8	-	κ_8	-	κ_8	0.289** (3.91)	κ_8	0.375** (5.30)	κ_8	-	κ_8	0.093 (1.24)
κ_9	0.130* (1.93)	κ_9	0.165** (2.29)	κ_9	0.284** (3.88)	κ_9	0.445** (5.96)	κ_9	-	κ_9	0.307** (3.965)
κ_{10}	0.095 (1.36)	κ_{10}	0.168** (2.29)	κ_{10}	0.308** (4.25)	κ_{10}	0.501** (6.78)	κ_{10}	-	κ_{10}	0.377** (4.926)
κ_{11}	-	κ_{11}	0.100 (1.37)	κ_{11}	0.290** (4.137)	κ_{11}	0.520** (7.32)	κ_{11}	-	κ_{11}	0.322** (4.21)

κ_{12}	-	κ_{12}	0.109* (1.83)	κ_{12}	0.222** (3.51)	κ_{12}	0.408** (7.10)	κ_{12}	-	κ_{12}	0.211** (3.13)
ω	0.0002 (1.02)	ω	0.0004 (1.31)	ω	0.0009 (1.458)	ω	0.0004 (1.41)	ω	-	ω	-
α	0.114** (2.16)	α	0.171** (2.26)	α	0.143* (1.91)	α	0.179** (2.13)	α	-	α	-
β	0.877** (14.31)	β	0.810** (10.05)	β	0.821** (9.962)	β	0.818** (10.95)	β	-	β	-

Panel B: Diagnostic tests on standardized residuals of GARCH-M models					Panel B: Diagnostic tests on residuals	
J-B test	41.02 [0.00]	26.14 [0.00]	294.53 [0.00]	114.82 [0.00]	7935 [0.00]	3431 [0.00]
Q(20)	9.352 [0.589]	29.247 [0.06]	12.46 [0.132]	16.36 [0.04]	19.48 [0.147]	15.27 [0.08]
$Q^2(20)$	16.616 [0.12]	22.124 [0.278]	8.781 [0.361]	9.46 [0.31]	7.89 [0.895]	19.34 [0.15]
ARCH(20)	0.804 [0.707]	0.761 [0.757]	0.8627 [0.616]	0.404 [0.98]	0.274 [0.993]	0.73 [0.783]
AIC	-2.232	-1.862	-1.367	-1.494	-1.84	-2.23
SBIC	-2.005	-1.605	-1.110	-1.237	-1.73	-2.04
R^2	0.370	0.532	0.626	0.739	0.607	0.660

Notes:

- All variables are transformed in natural logarithms
- ** and * indicate significance at the 5% and 10% levels, respectively
- Figures in parentheses $(\cdot)$ and in squared brackets $[\cdot]$ indicate t-statistics and exact significance levels, respectively
- J-B Normality is the Jarque and Bera (1980) normality test, with probability values in square brackets
- $Q(20)$ and $Q^2(20)$ are the Ljung and Box (1978) tests for 20th order serial correlation and heteroskedasticity in the standardized residuals and in the standardized squared residuals, respectively.
- ARCH(20) is the Engle's(1982) F test for Autoregressive Conditional Heteroskedasticity.
- The persistence coefficient is calculated as $\alpha + \beta$

4.2.3.3. Explaining the behavior of risk premiums

The results regarding the assumptions of rational expectations and the EMH in explaining the formation of period rates in shipping markets are in line with the findings of Kavussanos and Alizadeh (2002a), which do not support these assumptions.

Kavussanos and Alizadeh (2002a) argue that ship-owners operating in the spot market are generally exposed to four types of risks in comparison to those operating in time charter market, namely, the higher fluctuations of spot rates compared to time charter rates, the unemployment risk, the possible relocation loss and cost fluctuations when operating in the spot market. Thus, ship-owners operating in the time charter market are prepared to offer a discount to cover the risk which they are exposed to when operating in the spot market. Therefore, the charterer will take the risk of operating in the spot market during the life of the time charter contract subject to a discount over spot rates. The sentiment of the banks and lenders in shipping finance is another important factor in ship-owners' decisions to offer a discount to operate in the time charter market. Since this ensures a relatively more secure stream of income for ship-owner and reduces the probability of loan default. These findings are bolstered by negative risk premiums obtained through EGARCH-M models during the sample period Jan 1980 to Aug 1997.

Adland and Cullinane (2005) propose qualitative arguments regarding risk premiums without testing arguments by models. They suppose that shipowners and charterers face several kinds of risk factors, including the spot price volatility, the surplus supply, the excess demand, the default risk, liquidity risk and technological or regulatory obsolescence. Since risk factors depend on the state of spot freight market, risk premiums must also be time varying. The net risk premium is supposed to be negative during a weak freight market for both the short-term and long-term charter duration, while during a strong freight market, it is assumed to be positive for the short-term, and negative for the long-term.

In our section, we attribute the failure of the expectations theory to the existence of the market dependent risk premiums, signs and types of which vary with the state of the spot freight and market segments. The signs of risk premiums are summed up in Table 4.9 and some explanations are provided thereafter.

Table 4.9: Comparisons of risk premiums in three cases

	Sample period	*One-year/Spot*	*Three-year/Spot*	*One-year/Spot*	*Three-year/Spot*
Kavussanos and Alizadeh (2002a)	1980.01-1997.08	Negative	Negative	Negative	Negative
Adland and Cullinane (2005)	-	Positive(strong)	Negative(strong)	Negative(weak)	Negative(weak)
Our results	1990.01-2010.12	Negative(strong)	Negative(strong)	?(weak)	Near zero(weak)

Notes: strong in the parentheses means a strong freight market, weak implies a weak freight market.

In the Capesize and Panamax markets, the implied risk premium is time-varying, while it is constant in the Handymax market, as assumed in the traditional expectations theory. Regarding signs of risk premiums, the negative coefficients of risk premiums in our models during a strong freight market suggest that there is a negative relationship between the agents' perception of risk and the price of long-term shipping contracts, which are thought to be more secure than spot contracts. Because when the market is strong, ship-owners or charterers are not sure whether the booming trend will continue or not in the future, ship-owners, therefore, would be willing to offer a discount or prepared to pay for security to operate in the period market.

During a weak freight market, results reveal there is no significantly positive or negative risk premium in most cases. This may result from the diverse expectations on the future market. When the market remains sluggish, some ship-owners think the weak market will turn up soon, they may consequently ask for a positive risk premium to operate in the period market. While others believe the market will continue to drop, so they prefer to offer a negative risk premium to get a long-term period contract to compensate for the possible more risks in the spot market. The heterogeneous views about the market outlook result in neither positive nor negative risk premiums in the weak market, which may explain the insignificant risk premium observed from models in most cases.

Implications of the failure of the expectations theory are as follows. Firstly, the spot freight market is predictable due to the failure of the efficient market hypothesis. The past information can be useful in making forecasts. Secondly, the excess profits by switching between the period market and the spot market, may be made by operators who can get more information than others. And the risk dynamics in the spot market should be considered when determining models for pricing period rates. Thirdly, our results on the VAR model suggest that the information contained in time charter rates and dynamics between the spot and time charter rates may be used to improve forecasts of spot rates. Thus, based on the results of the Granger-causality from the spread to spot rates, it can be argued that the dynamic relationship between spot and period rates may be taken into account when predicting spot rates in the future.

4.3. Dynamic interrelationship between sub freight shipping sectors[4]

The dry bulk shipping market is generally classified by size and each size vessel is involved in the transportation of certain commodities. However, sometimes vessels of adjacent size categories are used as substitutes; for instance, Capesize instead of Panamax and vice versa. Such substitutions become more significant when the demand in one market is relatively higher than the other and is enough to attract other types of vessels to participate in the market and make a profit. In such cases, one would expect that shocks to one subsector might be transmitted to the others. For instance, if there is an increase in demand and, subsequently, freight rates for Capesize vessels, other size categories such as Panamax may react by participating in the Capesize market, if it is found to be profitable.

Beenstock and Vergottis (1993) investigate the spillover effects between tanker and dry bulk markets through the markets for combined carriers (combis), shipbuilding and scrapping markets using dynamic econometric models. They find that increasing dry cargo rates attract combis from the tanker market and meanwhile push shipyards to build more dry bulk vessels, finally causing an increase in tanker prices. Alizadeh (2001) extends the study by using modern econometric techniques, such as VAR, cointegration tests and impulse response analysis, instead of dynamic structural models, to examine the spillover effects between different segments within the dry bulk sector. Kavussanos and Visvikis (2004) examine for the first time the lead-lag relationship between spot and forward markets, both in terms of returns and volatilities. The causal relationships between spot and FFA returns in all routes are estimated by using VECM models, and volatility spillovers are investigated by the bivariate VECM-GARCH-X models.

This section investigates in detail the interrelationship between the Capesize and the Panamax markets. Specifically, it examines the dynamic relations between Capesize and Panamax prices in the spot market for four different routes, as well as spillovers of volatilities between the two markets during the period from 1999 to 2008. It is well known that the dry bulk market has recovered and run into an unexpected long period of boom from 2003 until September 2008, when the market began to collapse due to the world financial crisis. Consequently, the sample period is split into two. Because of different trading conditions on each route, the analysis is conducted for each route (the transatlantic, fronthaul, transpacific and backhaul) in order to clarify the different relationship between Capesize and Panamax prices in four major trading areas. We employ the daily TCT (Time Charter Rate on a Trip Basis) prices for the four routes in both Capesize and Panamax markets, published by the Baltic Exchange.

The research will shed light on important issues, such as how the mechanisms of the Capesize and the Panamax markets have worked over different periods, the degree of substitutability between the two markets in each trading area, and the dynamics in terms of returns and volatilities on different trading routes. The dynamics between the two markets may be used by the market players. Specifically, ship-owners can typically consider the risk/return trade-off to cover the risk exposure they face or to make profits by switching between the two markets. Charterers, on the other hand, may reduce freight costs by hiring the optimal size vessels.

The remainder of this section is organized as follows. The next sub section describes the methodology and the empirical models used in this section. This is followed by a presentation of the data properties. We then proceed to present the empirical results concerning the interrelationships between the Capesize and the Panamax markets, and the final section concludes the study.

---

[4] Section 4.3 is based on the paper 'Dynamic interrelationships in returns and volatilities between Capesize and Panamax markets', published on the *Journal of Maritime Economics and Logistics*, 2010

4.3.1. Methodology

A cointegration test is used to investigate a long-run equilibrium relationship between variables. Johansen (1988, 1991) procedures for testing cointegration are the most reliable approaches and, consequently, preferred by researchers. The first step in examining the cointegration relationships between variables, is to determine the order of integration of each price series using the Augmented Dickey-Fuller and Phillips-Perron tests (Dickey and Fuller, 1981; Phillips and Perron, 1988). Given a set of two I(1) series, the following VECM (Johansen, 1988) is estimated, explained extensively in Appendix A:

$$\Delta X_t = \mu + \sum_{i=1}^{p-1} \Gamma_i \Delta X_{t-i} + \prod X_{t-1} + \varepsilon_t,\ \varepsilon_t \left| \Omega_{t-1} \sim distr(0, H_t) \right. \tag{4.22}$$

Here X_t is the 2×1 vector of log time charter rates for different ship sizes, respectively. Δ denotes the first difference operator, ε_t is a 2×1 vector of error terms $(\varepsilon_{c,t}, \varepsilon_{p,t})'$, following an as-yet-unspecified conditional distribution with mean zero and time-varying covariance H_t. Γ_i and $\prod$ are coefficient matrices. The VECM specification contains information on both the short- and long-run adjustment to changes in X_t via the estimates of Γ_i and $\prod$ respectively.

For instance, if the Capesize and Panamax prices are cointegrated, then causality must exist in at least one direction (Granger, 1988). Granger causality can identify whether two variables move one after the other or contemporaneously. When they move contemporaneously, one provides no information for characterizing the other. If X causes Y, then changes in X should precede changes in Y, and vice versa.

In order to examine the volatility spillovers, the conditional variations of returns in both markets are measured using the family ARCH models. In this section, the conditional second moments of Capesize and Panamax returns are specified as GARCH (1, 1)-X, using the following representation:

$$H_t = C'C + A'\varepsilon_{t-1}\varepsilon'_{t-1}A + B'H_{t-1}B + D'_1 e_{1t-1}e'_{1t-1}D_1 + D'_2 e_{2t-1}e'_{2t-1}D_2 \tag{4.23}$$

Here C is a 2×2 lower triangular matrix, A and B are 2×2 diagonal coefficient matrices with $\alpha^2{}_{ii} + \beta^2{}_{ii} < 1, i = 1,2$ for stationarity, and D_1 and D_2 are 1×2 vectors of coefficients which contain parameters of spillover effects. e_{1t-1} and e_{2t-1} represent additional explanatory variables which belong to Ω_{t-1} and influence H_t. For instance, e_{1t-1} is the matrix whose elements are the lagged error terms of the Capesize mean equation, representing the volatility spillover effect from the Capesize to the Panamax market. e_{2t-1} is the matrix whose elements are the lagged error terms of the Panamax mean equation, representing the volatility spillover effect from the Panamax to the Capesize market.

In this diagonal representation, the conditional variances are a function of their own lagged values, their own lagged error terms and volatility spillover terms, while the conditional covariance is a function of lagged covariances and lagged cross-products of the $\varepsilon_t \varepsilon_t'$. Moreover, this formulation guarantees H_t to be almost definitely positive for all t. Finally, the most parsimonious specification for each model is estimated by excluding insignificant variables.

Preliminary evidence on our data set with the conditional normal distribution reveals substantial excess kurtosis in the estimated standardized residuals. Therefore, following Bollerslev (1987), the conditional Student-t distribution is used as the density function of the error terms ε_t and the number of degrees of freedom, v, is treated as another parameter to be estimated. When the number of degrees of freedom, v, is lower than 4, Baillie and Bollerslev (1995) show that the Student-t distribution has an infinite kurtosis, for the theoretical kurtosis is computed as $3(v-2)/(v-4)$. In such cases, the methods described by Bollerslev and Wooldridge (1992) are preferred for estimating robust quasi-maximum likelihood (QML) covariance and standard errors. The QML is used in the estimation of the ECM-GARCH models in some of the investigated routes.

4.3.2. Data description and statistical properties

The dry bulk shipping market is generally divided into three sub-markets by ship size: the Capesize, the Panamax and the Handymax/Handy markets. Each size ship is involved in the transportation of certain types of commodities in each trading route. The majority of Capesize vessels are engaged in the transportation of iron-ore, mainly from Brazil and Australia, and also coal from Australia, South Africa and South America. Panamax ships are primarily used for iron ore exports from Brazil and Australia, coal exports from America, South Africa and Australia, grain exports from North America, Argentina and Australia, as well as the transportation of bauxite and phosphate. Handymax vessels are used to transport grain, coal and minor bulks from all over the world.

In the three sub-markets, the main trading routes for Capesize and Panamax vessels are overlapping i.e. the transatlantic, the fronthaul, the transpacific and the backhaul. Since there are nine trading routes for Handymax vessels, the overlapping routes for Panamax and Handymax vessels are the fronthaul, the transpacific and the backhaul. The route descriptions are reported in Table 4.10. In major trading routes, overlapping cargoes carried by Capesize and Panamax vessels are iron ore and coal, and those carried by Panamax and Handymax vessels are coal, grain and sometimes iron ore. Therefore, Capesize and Panamax sub-markets, and Panamax and Handymax sub-markets are, to some extent, linked through the transportation of overlapping cargoes on specific routes.

Table 4.10: Descriptions of overlapping routes for Capesize, Panamax and Handymax vessels

Type	*Route*	*Route description*	*Vessel size (dwt)*	*Cargoes**
Capesize	Transatlantic (TAC)	Delivery Gibraltar -Hamburg range, trans Atlantic round voyage duration 30 -45 days, redelivery Gibraltar-Hamburg range	172,000/161,000	Iron Ore, coal
	Fronthaul (FHC)	Delivery Amsterdam-Rotterdam-Antwerp range or passing Passero, redelivery China -Japan range, duration about 65 days	172,000/161,000	Iron ore, coal
	Transpacific (TPC)	Delivery China -Japan range, round voyage duration 30-40 days, redelivery China-Japan range	172,000/161,000	Iron ore, coal
	Backhaul (BHC)	Delivery China -Japan range, redelivery Amsterdam-Rotterdam-Antwerp range or passing Passero, duration about 65 days	172,000/161,000	Coal
Panamax	Transatlantic (TAP)	A trans Atlantic (including ECSA) round of 45/60 days on the basis of delivery and redelivery Skaw - Gibraltar range	74,000/70,000	Diverse
	Fronthaul (FHP)	Basis delivery Skaw -Gibraltar range, for a trip to the Far East, redelivery Taiwan -Japan range, duration 60/65 days	74,000/70,000	Grain, iron ore, coal
	Transpacific (TPP)	Pacific round of 35/50 days either via Australia or Pacific, delivery and redelivery Japan/South Korea range	74,000/70,000	Grain, iron ore, coal, sulphur, bauxite
	Backhaul (BHP)	Delivery Japan -South Korea range for a trip via US West Coast-British Columbia range, redelivery Skaw-Gibraltar range, duration 50/60 days	74,000/70,000	Coal, cement clinker, coke
Handymax	Fronthaul (FHH)	Delivery Antwerp/Skaw range for a trip of 60/65 days redelivery Singapore/Japan range including China	45,496/52,454	grain, minor bulks
	Transpacific (TPH)	Delivery South Korea/Japan range for 1 Australian or trans Pacific round voyage, for a 35/40 day trip, redelivery South Korea/Japan range	45,496/52,454	Coal, iron ore minor bulks
	Backhaul (BHH)	Delivery South Korea/Japan range for a trip of 60/65 days redelivery Gibraltar/Skaw range	45,496/52,454	minor bulks

Source: Baltic Exchange (2010)
Notes: The transatlantic is also called the T/A RV; the fronthaul route is also known as the Cont-Med Trip FE; the transpacific route is known as the T/P RV and the backhaul route is also called the FE Trip Cont-med.

* means that the information concerning main cargoes in each trading route is obtained from ship-broking companies

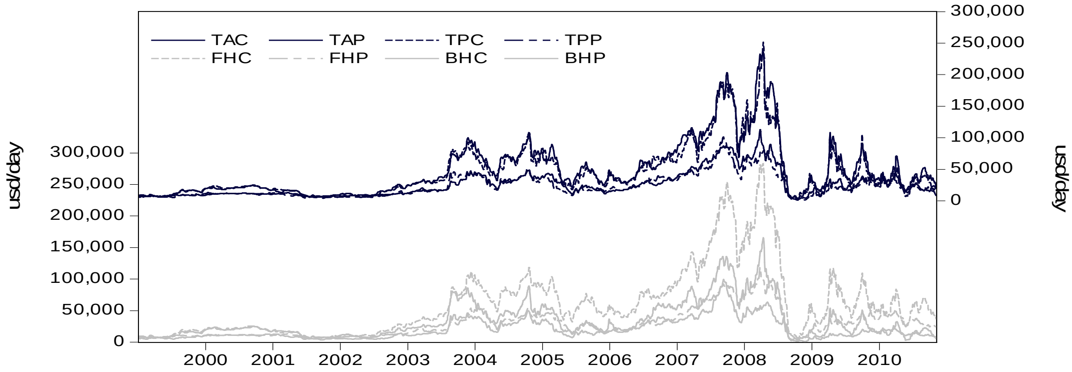

Figure 4.6: Trends of daily time charter rates for the Capesize and Panamax sectors on all routes from March 1st 1999 to December 24th 2010.

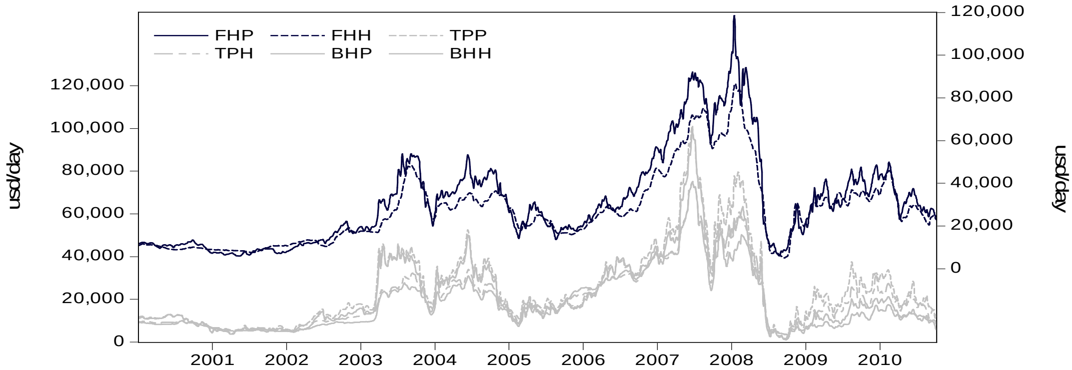

Figure 4.7: Trends of daily time charter rates for the Panamax and Handymax sectors on three routes from September 4th 2000 to December 24th 2010.

Notes: BHC = Backhaul Capesize, BHP = Backhaul Panamax, FHC = Fronthaul Capesize, FHP = Fronthaul Panamax, TAC = Transatlantic Capesize, TAP = Transatlantic Panamax, TPC = Transpacific Capesize, TPP = Transpacific Panamax, FHH = Fronthaul Handymax, TPH=Transatlantic Handymax, BHH=Backhaul Handymax

In this section, daily benchmark TCT rates of Capesize and Panamax markets in each trading route reported by the Baltic Exchange are used during the sample period of March 1st 1999 to Dec 24th, 2010. Because Baltic Exchange started reporting daily TCT rates for Handymax vessels on Sept 4th, 2000, the sample period for Handymax starts from Sept 4th, 2000 to Dec 24th, 2010. It is clearly revealed in Figures 4.6-4.7 that the prices have changed dramatically and the trends have been distinctly different since 2003. During the period from 1999 to 2002, the dry bulk market was mostly stuck in troughs, resulting from the world economic recession and terrorist attack in 2001. However, from 2003 to 2007, the global economy experienced strong and uninterrupted growth. This growth has created a big increase in demand for shipping services, leading directly to an extraordinary dry bulk shipping boom until the financial crisis in July, 2008. Since then, the dry bulk market has collapsed and moved into recession.

In addition, from January 2nd 2003, the BCI time charter vessel description was officially increased to 172,000 dwt and the BPI description to 74,000 dwt, while previously the benchmark time charter rates for Capesize and Panamax were assessed on the standard vessel size of 161,000 dwt and 70,000dwt respectively. For Handymax vessels, the vessel size was officially increased to 52, 454 dwt on 3rd Jan, 2006 from 45, 496 dwt.

Changes in the economic conditions and benchmark vessel size may create structural breaks in all price series over the whole period. If they are incorporated in the analysis, significant serial correlation and a non-stationary GARCH process can be demonstrated for the residuals of the mean equations. Therefore, for Capesize and Panamax, the whole sample period is split into three: the first is from March 1st 1999 to December 24th 2002, the second runs from January 3rd 2003 to August 29th 2008, and the rest from Oct 1st, 2008 to Dec 24th, 2010. For Panamax and Handymax vessels, the first is from Sept 4th, 2000 to Dec 24th 2003, the second is from Jan 3rd 2003 to Aug 29th 2008, when it is again split due to the increase in Handymax benchmark ship size in Jan 2006, and the third period runs from Oct 1st2008 to Dec 24th, 2010.

All original figures are switched into logarithms for the analysis. Summary statistics of logarithmic first differences of daily time charter rates for Capesize, Panamax and Handymax vessels during sub-periods are presented in Tables 4.11-4.12.

For Capesize and Panamax markets, results in Table 4.11 show that over the first sub-period, excess skewness and kurtosis are seen in all price series. Data with excess kurtosis tend to have distinct peaks near means and drop quickly. The Jarque and Bera (1980) tests reject the hypothesis of normality (skewness=0, kurtosis=3) for all series. The Ljung-Box Q(36) and $Q^2(36)$ statistics (Ljung and Box, 1978) on the first 36 lags of the sample autocorrelation function of the logarithmic first different series and of the log-squared series indicate, respectively, significant serial correlation and the existence of heteroskedasticity. The existence of serial correlation in all series may result from two factors. On the one hand, it stems from the way ship-broking companies determine the time charter rates. Each rate assessment is either made on an actual fixture or, in the absence of an actual fixture, made on the previous day's level. On the other hand, ship-owners and charterers may revise their rates based on the benchmark price levels. Both of these will induce autocorrelation in route rates. We use the Augmented Dicky-Fuller and Phillips-Perron (Dickey and Fuller, 1981; Phillips and Perron, 1988) unit root tests on the log levels and log-first differences of the price series and the results show that all variables are integrated of order one.

The summary statistics of all price series for Capesize and Panamax markets during the second and the third sub-periods are also reported in Table 4.11. The results indicate that all the series over these two sub-periods are leptokurtic, non-normal, autocorrelated and heteroscedastic at any conventional significance levels. A comparison of sample standard deviations among all sub-periods reveals that both Capesize and Panamax prices fluctuate most over the third sub-period and the second sub-period next. The first sub-period witnesses the steadiest movement of prices for both Capesize and Panamax vessels. Also, Capesize prices are more volatile than Panamax ones for all cases.

For Handymax market, the summary statistics of the price series during all sub-periods are reported in Table 4.12. The non-normality, autocorrelation and heteroskedasticity are evident at any conventional significance levels for all price series. A comparison of sample standard deviations between Panamax and Handymax markets indicates that the Handymax variation in rates of price changes over all sub-periods is significant lower than that of the bigger ship size, and the comparison of the sample standard deviations over all sub-periods in Table 4.12 also displays that the third sub-period sees the most volatility for Handymax prices, and the first sub-period the least.

Table 4.11: Descriptive statistics of logarithmic first differences of time charter rates for Capesize and Panamax sectors

	N	Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Q(36)	Q^2(36)	ADF(lags)	PP(12)	ADF(lags)	PP(12)
									Lev	Lev	1st diffs	1st diffs
Period 1: Average time charter rates for Capesize and Panamax (01/03/1999-24/12/2002)												
ILTAC	961	0.0011	0.0159	1.132[0.00]	9.3568[0.00]	1823.16[0.00]	1672.8	350.1	-1.6728(2)	-1.234	-9.288(1)	-10.651
ILTAP	961	0.0004	0.0123	0.288[0.00]	5.2211[0.00]	210.823[0.00]	1802.4	774.8	-2.6655(1)	-1.852	-9.691(0)	-9.624
ILFHC	961	0.0011	0.0147	0.666[0.00]	6.7304[0.00]	628.359[0.00]	1561.8	470.2	-1.2759(1)	-1.179	-11.333(0)	-11.571
ILFHP	961	0.0004	0.0124	0.847[0.00]	7.4155[0.00]	895.579[0.00]	1353.8	558.58	-2.5487(1)	-1.713	-11.163(0)	-10.882
ILTPC	961	0.0009	0.0160	1.634[0.00]	12.48[0.00]	4026.07[0.00]	1726.7	384.76	-1.4689(1)	-1.189	-10.928(0)	-10.926
ILTPP	961	0.0008	0.0177	0.773[0.00]	5.9577[0.00]	445.875[0.00]	1546.5	772.02	-2.3264(3)	-1.718	-10.956(0)	-9.246
ILBHC	961	0.0008	0.0158	1.126[0.00]	9.7209[0.00]	2011.96[0.00]	1735.7	563.81	-1.5889(1)	-1.253	-10.662(0)	-10.556
ILBHP	961	0.0007	0.0173	0.652[0.00]	7.3681[0.00]	832.017[0.00]	1409.9	450.68	-2.1800(1)	-1.401	-11.216(3)	-10.052
Period 2: Average time charter rates for Capesize and Panamax (03/01/2003-29/08/2008)												
ILTAC	1417	0.0011	0.0268	-0.413[0.00]	12.848[0.00]	5766.59[0.00]	1234.2	301.2	-2.154(2)	-2.015	-15.905(1)	-14.832
ILTAP	1417	0.0012	0.0207	0.023[0.00]	5.5627[0.00]	387.887[0.00]	1567.4	833.2	-1.862(2)	-1.783	-15.646(1)	-10.329
ILFHC	1417	0.0013	0.0225	-0.201[0.00]	6.3895[0.00]	687.820[0.00]	1240.8	425.3	-1.918(2)	-1.832	-17.235(1)	-12.282
ILFHP	1417	0.0012	0.0189	0.019[0.00]	5.4237[0.00]	347.245[0.00]	1589	981.8	-1.703(2)	-1.659	-16.205(1)	-9.9811
ILTPC	1417	0.00118	0.0331	0.009[0.00]	11.666[0.00]	4433.51[0.00]	895.9	261.1	-2.122(2)	-2.0	-15.159(1)	-14.624
ILTPP	1417	0.00065	0.0264	0.274[0.00]	5.7144[0.00]	452.710[0.00]	1750.8	1238.5	-2.301(2)	-2.103	-16.137(1)	-9.201
ILBHC	1417	0.00095	0.0284	0.176[0.00]	8.3378[0.00]	1689.52[0.00]	1187.2	420.5	-1.980(3)	-1.933	-17.539(2)	-13.627
ILBHP	1417	0.00063	0.0249	0.350[0.00]	6.3252[0.00]	681.740[0.00]	1665	1310.9	-2.029(4)	-2.065	-15.074(3)	-9.798
Period 3: Average time charter rates for Capesize and Panamax (01/09/2008-24/12/2010)												
ILTAC	583	-0.003	0.071	0.513[0.00]	9.160[0.00]	947.268[0.00]	652.44	280.4	-2.756(1)	-2.467	-10.015(0)	-9.695
ILTAP	583	-0.002	0.045	-0.257[0.00]	5.872[0.00]	206.787[0.00]	878.02	564.38	-2.525(2)	-2.296	-9.601(1)	-6.879
ILFHC	583	-0.003	0.054	0.363[0.00]	7.044[0.00]	410.113[0.00]	695.05	187.63	-2.499(2)	-2.549	-11.03(1)	-9.687
ILFHP	583	-0.002	0.032	-0.92[0.00]	8.194[0.00]	737.474[0.00]	897.47	507.87	-2.371(2)	-2.219	-9.615(1)	-7.207
ILTPC	583	-0.003	0.083	0.823[0.00]	8.964[0.00]	929.950[0.00]	443.40	131.70	-2.815(2)	-11.285	-2.786(12)	-10.382
ILTPP	583	-0.002	0.055	0.492[0.00]	8.054[0.00]	643.987[0.00]	761.97	561.03	-2.282(2)	-2.038	-9.880(1)	-7.226
ILBHC	583	-0.004	0.070	0.247[0.00]	9.333[0.00]	980.096[0.00]	677.18	167.24	-2.863(2)	-2.835	-10.215(1)	-9.026
ILBHP	583	-0.003	0.051	0.123[0.00]	8.175[0.00]	651.993[0.00]	880.95	1078.4	-2.560(2)	-2.298	-2.298(14)	-6.605

Notes:

- All series are measured in logarithmic first differences. N is the number of observations.
- ILTAC and ILTAP mean logarithmic first difference of daily time charter rates for the Capesize and Panamax respectively on the transatlantic route; ILFHC and ILFHP mean that on the fronthaul route; ILTPC and ILTPP mean that on the transpacific route; ILBHC and ILBHP mean that on the backhaul route.
- Q(36) and Q^2(36) are the Ljung and Box (1978) Q statistics on the first 36 lags of the sample autocorrelation function of the raw series and of the squared series, distributed as $\chi^2(36)$ .The critical values are 58.11 and 51.48 for the 1% and 5% levels, respectively.
- The 5% critical value for the ADF and PP tests is -2.864. -2.863, -2.866 during the first, the second and the third sub-period, respectively.
- See others to Table 4.4

Table 4.12: Descriptive statistics of logarithmic first differences of time charter rates for the Handymax sector

	N	Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Q(36)	$Q^2(36)$	ADF(lags)	PP(12)	ADF(lags)	PP
									Lev	Lev	1st diffs	1st diffs
Period 1: Average time charter rates for Handymax (04/09/2000-24/12/2002)												
ILFHH	582	0.000	0.004	0.283 [0.00]	5.795 [0.00]	197.150 [0.00]	1867.6	313.03	-1.384(3)	-0.673	-5.746(2)	-10.971
ILTPH	582	0.000	0.006	1.066 [0.00]	6.407 [0.00]	391.652 [0.00]	1419.3	828.26	-1.023(1)	-0.874	-6.404(2)	-12.771
ILBHH	582	0.000	0.006	0.729 [0.00]	4.486 [0.00]	105.138 [0.00]	1397.7	519.42	-1.422(3)	-1.263	-6.209(2)	-12.304
Period 2 Ⅰ: Average time charter rates for Handymax (03/01/2003-23/12/2005)												
ILFHH	750	0.001	0.010	0.277 [0.00]	5.454 [0.00]	197.795 [0.00]	2717.4	740.05	-2.337(1)	-2.007	-6.821(0)	-6.907
ILTPH	750	0.001	0.017	1.660 [0.00]	15.695 [0.00]	5380.55 [0.00]	1612.9	239.32	-2.450(1)	-1.951	-7.813(0)	-8.163
ILBHH	750	0.001	0.018	3.015 [0.00]	32.811 [0.00]	28908.5 [0.00]	1604.7	112.80	-2.256(1)	-1.959	-8.227(0)	-8.027
Period 2 Ⅱ: Average time charter rates for Supramax (03/01/2006-29/08/2008)												
ILFHH	667	0.001	0.008	0.692 [0.00]	10.156 [0.00]	1476.31 [0.00]	1750.8	1238.5	-1.210(2)	-0.989	-6.689(1)	-9.210
ILTPH	667	0.001	0.015	0.830 [0.00]	12.993 [0.00]	2851.59 [0.00]	1187.2	420.5	-2.362(2)	-2.107	-7.032(1)	-8.286
ILBHH	667	0.001	0.016	1.431 [0.00]	18.204 [0.00]	6651.85 [0.00]	1665	1310.9	-2.702(1)	-2.659	-8.992(0)	-8.858
Period 3: Average time charter rates for Supramax (01/09/2008-24/12/2012)												
ILFHH	583	-0.001	0.026	1.733 [0.00]	20.179 [0.00]	7460.935 [0.00]	13001	415.4	-2.224(1)	-2.098	-6.949(0)	-6.663
ILTPH	583	-0.002	0.031	0.387 [0.00]	6.696 [0.00]	346.416 [0.00]	1112	334.4	-2.401(1)	-2.218	-7.724(0)	-7.836
ILBHH	583	-0.002	0.026	-0.262 [0.00]	7.026 [0.00]	400.41 [0.00]	1200.5	933.9	-2.850(1)	-2.782	-7.698(0)	-7.654

Notes: ILFHH means logarithmic first difference of daily time charter rates for Handymax on the fronthaul route; ILTPH means that on the transpacific route; ILBHH means that on the backhaul route. See other notes to Table 4.11.

4.3.3. Dynamic relationships between Capesize and Panamax sub-markets

Cointegration tests are executed using Capesize and Panamax prices over all sample routes during three sub-periods and a VECM-SURE model is employed to estimate the parameters of each equation. Some insight was gained into the causal relationship between both price series and also the information transmission between the two markets. All the results below are explained in an economic manner, so as to obtain a clearer picture of the dynamic relationship in these two markets over the whole period.

4.3.3.1. Cointegration between Capesize and Panamax sub-markets

Having identified that the daily time charter rates are all $I(1)$ variables, the Johansen (1988) procedure is employed in order to test for cointegration between Capesize and Panamax prices for all routes. The Schwarz Bayesian Information Criterion (Schwarz, 1978), Akaike Information Criterion (Akaike, 1973) and LR test were used to determine the lag length in the models during both sub-periods. The results of the cointegration test are presented in Table 4.13.

The first sub-period

The examination of the cointegration relationship between Capesize and Panamax prices is carried out during the period from March 1st 1999 to 24th December 2002. The estimated $\lambda_{\max}$ and λ_{trace} statistics show that the Capesize and Panamax prices on all routes are cointegrated at the 5% significance level. The shipping demand for iron ore and coal is the underlying fundamental for the cointegration relationship between the two markets.

In order to provide some insight into short-run parameters of both equations, the models are estimated using seemingly unrelated regressions estimation (SURE). The SURE method is used because a gain in efficiency can occur when a particular equation is considered as part of the system, if models are formulated with constraints across both equations. Because residual diagnostics tests indicate the existence of autocorrelation and heteroskedasticity for the residuals of the Capesize mean equations in all routes, so the standard errors and t statistics of the estimated coefficients are adjusted by the Newey-West correction for serial correlation and heteroskedasticity (Newey and West, 1987).

The estimation results of the VECM models for the first sub-period are reported in Table 4.14. It can be seen that the coefficients of the error correction term (ECT) of the Capesize equation are significant at the 10% level, but not at the conventional 5% level in the transatlantic and the backhaul route. While in the transpacific and the fronthaul routes, the parameters of ECTs for both equations are significant at the 5% significance level. More rigorous investigation of the interactions between the variables can be obtained by performing Granger causality tests, which are presented in the same Table. The results reveal that in all routes, Panamax prices Granger cause Capesize prices, while Capesize prices do not Granger cause Panamax prices at the 5% significance level.

The unidirectional causality from the Panamax to the Capesize may be explained by the economic conditions and different market features during the period of analysis. Over the first sub-period, the dry bulk market was mostly stuck in troughs with the exception of short booms in 2000. At the same time, annual seaborne trade of iron ore and coal, the main cargoes for Capesize carriers, increased steadily, causing a sustainable demand for large carriers on long distance voyage. During the period before 2003, many Capesize carriers were controlled by some large shipowners and it was quite common for deals to agreed confidentially between parties. In the absence of real Capesize trades or actual Capesize prices, the panelists of the Baltic Exchange may report prices that are more arbitrarily arrived at. Under such circumstances, Capesize prices may not contain significant predictive power of future movements due to the lower market transparency.

Table 4.13: Johansen (1988) tests for the number of cointegrating vectors between Capesize and Panamax prices

	Lags	*Hypothesis (maximal)*		*Test statistic*	*Hypothesis (trace)*		*Test statistic*	*95% Critical values*		Cointegrating vector
		H_0	H_1	$\lambda_{\max}$	H_0	H_1	λ_{trace}	$\lambda_{\max}$	λ_{trace}	$\beta' = (1, \beta_1, \beta_2)$
Period1										
TA	1	$r=0$	$r=1$	22.38	$r=0$	$r=1$	25.44	15.67	19.96	(1, 9.473,-2.082)
		$r \le 1$	$r=2$	3.06	$r \le 1$	$r=2$	3.06	9.24	9.24	
FH	1	$r=0$	$r=1$	21.59	$r=0$	$r=1$	23.93	15.67	19.96	(1,11.837, -2.334)
		$r \le 1$	$r=2$	2.34	$r \le 1$	$r=2$	2.34	9.24	9.24	
TP	1	$r=0$	$r=1$	38.21	$r=0$	$r=1$	40.69	15.67	19.96	(1, 3.924,-1.483)
		$r \le 1$	$r=2$	2.493	$r \le 1$	$r=2$	2.493	9.24	9.24	
BH	1	$r=0$	$r=1$	24.52	$r=0$	$r=1$	27.11	15.67	19.96	(1, 2.3738,-1.324)
		$r \le 1$	$r=2$	2.59	$r \le 1$	$r=2$	2.59	9.24	9.24	
Period 2										
TA	2,4	$r=0$	$r=1$	35.01	$r=0$	$r=1$	30.30	15.67	19.96	(1, -0.575, -1.011)
		$r \le 1$	$r=2$	4.29	$r \le 1$	$r=2$	4.29	9.24	9.24	(1,-0.6907, -1)*
FH	2,5	$r=0$	$r=1$	25.398	$r=0$	$r=1$	29.936	15.67	19.96	(1, -0.263, -1.051)
		$r \le 1$	$r=2$	4.54	$r \le 1$	$r=2$	4.54	9.24	9.24	(1,-0,802, -1)*
TP	2	$r=0$	$r=1$	41.785	$r=0$	$r=1$	46.61	15.67	19.96	(1,0.3692, -1.103)
		$r \le 1$	$r=2$	4.82	$r \le 1$	$r=2$	4.82	9.24	9.24	(1,-0,695, -1)*
BH	2	$r=0$	$r=1$	26.23	$r=0$	$r=1$	30.61	15.67	19.96	(1, 0.29, -1.08)
		$r \le 1$	$r=2$	4.38	$r \le 1$	$r=2$	4.38	9.24	9.24	(1,-0.52, -1)*
Period 3										
TA	2,6	$r=0$	$r=1$	15.094	$r=0$	$r=1$	21.615	15.89	20.262	-
		$r \le 1$	$r=2$	6.522	$r \le 1$	$r=2$	6.522	9.165	9.165	
FH	2	$r=0$	$r=1$	11.404	$r=0$	$r=1$	17.523	15.89	20.262	-
		$r \le 1$	$r=2$	6.119	$r \le 1$	$r=2$	6.119	9.165	9.165	
TP	2	$r=0$	$r=1$	13.749	$r=0$	$r=1$	19.735	15.89	20.262	-
		$r \le 1$	$r=2$	5.987	$r \le 1$	$r=2$	5.987	9.165	9.165	
BH	2	$r=0$	$r=1$	26.23	$r=0$	$r=1$	19.453	15.89	20.262	-
		$r \le 1$	$r=2$	4.38	$r \le 1$	$r=2$	7.551	9.165	9.165	

Notes:

- TA, FH, TP and BH refer to the transatlantic, the fronthaul, the transpacific and the backhaul route, respectively.
- Lags is the lag length of a VAR model; the lag length is determined using the SBIC (Schwarz, 1978), AIC (Akaike, 1973) and LR tests.
- r represents the number of cointegrating vectors, $\lambda_{\max}(r, r+1) = -T\ln(1-\hat{\lambda}_{r+1})$ and $\lambda_{trace}(r) = -T\sum_{i=r+1}^{n}\ln(1-\hat{\lambda}_i)$ where $\hat{\lambda}_i$ are the estimated eigenvalues of the $\prod$ matrix in Eq.(1). Critical values are from Osterwald-Lenum (1992), Table1.
- Estimates of the coefficients in the cointegrating vector are normalized with respect to the coefficient of the Panamax. The statistic for the parameter restrictions on the coefficients of the cointegrating vector is $-T[\ln(1-\hat{\lambda}_1 *) - \ln(1-\hat{\lambda}_1)]$ where $\hat{\lambda}_1 *$ and $\hat{\lambda}_1$ denote the largest eigenvalues of the restricted and the unrestricted models, respectively. The statistic is distributed as χ^2 with degrees of freedom equal to the total number of restrictions minus the number of the just identifying restrictions, i.e. the number of restrictions placed on the cointegrating vector.
- * refers to the restrictions imposed on cointegrating vectors. These restrictions are accepted at conventional significance levels in all routes. $\beta' = (1, -0.6907, -1)$ in the transatlantic route with p-value of 0.7212; $\beta' = (1, -0.802, -1)$ in the fronthaul route with p-value of 0.3033; $\beta' = (1, -0.695, -1)$ in the transpacific route with p-value of 0.1866; $\beta' = (1, -0.52, -1)$ in the backhaul route with p-value of 0.7081. The 1% critical values of $\lambda_{\max}$ and λ_{trace} for H_0 are 24.6 and 20.2, respectively; for H_1 both are 12.97.

In the Panamax market, more shipowners were engaged in competing for the same business. In addition to iron ore and coal, cargoes like grain, phosphate, and bauxite are all main commodities carried by Panamax vessels. The seaborne trade for these cargoes tumbled during the economic recession in 2001. Therefore, shipowners of Panamax vessels faced more risks and could be sensitive to market innovations. Panamax prices, therefore, may convey more market information and react faster to market shocks. As a consequence, the Capesize and Panamax prices differ in their ability to incorporate market information during the first sub-period, resulting in the fact that Panamax prices Granger cause Capesize prices without the feedback effect.

The second sub-period

The examination of the cointegration relationship between Capesize and Panamax prices is carried out during the period from 3rd 2003 to 29th Aug 2008. During the second sub-period, both series are cointegrated at conventional significance levels for all routes and thus have a long-run relationship between them. In order to gain more insight into the short-run movement of both prices, a VECM model is estimated for each route using seemingly unrelated regressions estimation (SURE). The results are reported in Table 4.15. Because the residual diagnostic tests, presented in Table 4.15 panel B, show the existence of heteroskedasticity on all routes, the t -statistics in panel A are adjusted by the White (1980) heteroskedasticity correction. The coefficients of the ECTs in the Capesize equations are statistically significant and negative, while the coefficients of the ECTs in the Panamax equations are statistically significant and positive. This implies that both Capesize and Panamax time charter rates respond to correct a shock to the system in order to reach the long-run equilibrium. For example, in response to a positive deviation from their equilibrium relationship at period $t-1$, Panamax prices in the next period increase in value and Capesize decrease in value, thus eliminating any disequilibrium.

The important element of the cointegrating relationship is the error correction term, $LC_{t-1} - \beta_2 LP_{t-1} - \beta_1$, which is in fact the difference between log Capesize prices and log Panamax prices. If β_2 is equal to unity, then the constant term β_1 is the long-run average of the log $Cape/Pnm$ ratios. Restrictions are imposed on the cointegrating parameters to yield LC/LP ratios of 0.691, 0.8, 0.6668 and 0.696, respectively, for the transatlantic, the fronthaul, the transpacific and the backhaul routes. In other words, the long-run average ratio of daily time charter rates for the Capesize sector versus the Panamax sector is 2 times in the transpacific route, 2.23 times in the fronthaul, 2 times in the transpacific and roughly 1.7 times in the backhaul. When the log $Cape/Pnm$ ratio is greater than its long-run average, this indicates Capesize prices are overestimated in comparison with Panamax prices, and Panamax vessels may be attracted to participate in the transportation of large consignments in the Capesize market when charterers find it profiTable to do so. In this case, Capesize prices will adjust in future periods by falling relative to their current levels. When the ratio is lower than its long-run mean, it implies Capesize prices are underestimated or Panamax overestimated. Sometimes it will be the occasion that Capesize vessels will take part cargoes where port characteristics or conditions permit.

Adjusted Wald tests on the joint significance of the lags in both equations (in the unrestricted VECM) imply the existence of a two-way feedback causal relationship between the two markets. Additionally, the coefficients of the Panamax lags in the Capesize equations are broadly larger in magnitude than the coefficients of the Capesize lags in the Panamax equations on all routes. Thus, it seems that Capesize prices play a leading role in incorporating new information on these routes. This can also be justified by the fact that the coefficient of ECT in the Capesize equation is larger in magnitude than in the Panamax equation, implying that the Capesize prices react quicker to information and reach equilibrium faster.

Table 4.14: Estimates of the VECM-SURE for Capesize and Panamax prices on four major routes （1999.3.1-2002.12.24）

$$\Delta C_t = \sum_{i=1}^{p-1} a_{c,i}\Delta C_{t-i} + \sum_{i=1}^{p-1} b_{c,i}\Delta P_{t-i} + w_c Z_{t-1} + \varepsilon_{c,t}$$

$$\Delta P_t = \sum_{i=1}^{p-1} a_{p,i}\Delta C_{t-i} + \sum_{i=1}^{p-1} b_{p,i}\Delta P_{t-i} + w_p Z_{t-1} + \varepsilon_{p,t},\ \varepsilon_t = \begin{pmatrix}\varepsilon_{c,i}\\ \varepsilon_{p,i}\end{pmatrix}\Big| \Omega_{t-1} \sim distr(0, H_t)$$

Panel A: VECM-SURE model estimates

Transatlantic		Fronthaul		Transpacific		Backhaul	
ΔC_t	ΔP_t	ΔC_t	ΔP_t	ΔC_t	ΔP_t	ΔC_t	ΔP_t
w_c -0.0021** (-1.7584)	w_p 0.00398* (3.62)	w_c -0.0024* (-1.973)	w_p 0.00429* (2.9965)	w_c -0.0038* (-2.5794)	w_p 0.00825* (4.4647)	w_c -0.0028** (-1.8563)	w_p 0.0068* (3.7559)
$a_{c,1}$ 0.7754* (13.8257)	$a_{p,1}$ 0.0248 (1.6308)	$a_{c,1}$ 0.742* (27.375)	$a_{p,1}$ 0.0241 (1.368)	$a_{c,1}$ 0.7714* (13.889)	$a_{p,1}$ -	$a_{c,1}$ 0.7813* (12.015)	$a_{p,1}$ -
$b_{c,1}$ 0.0705* (2.7699)	$b_{p,1}$ 0.8163* (29.13)	$b_{c,1}$ 0.095* (3.4172)	$b_{p,1}$ 0.77 (16.601)	$b_{c,1}$ 0.0378** (1.7714)	$b_{p,1}$ 0.8304* (28.013)	$b_{c,1}$ 0.0396** (1.821)	$b_{p,1}$ 0.7942* (23.095)
Causality test	Statistics	Causality test	Statistics	Causality test	Statistics	Causality test	Statistics
$\Delta C_t \rightarrow \Delta P_t$	3.089 [0.08]	$\Delta C_t \rightarrow \Delta P_t$	1.7817[0.180]	$\Delta C_t \rightarrow \Delta P_t$	0.0186[0.89]	$\Delta C_t \rightarrow \Delta P_t$	0.0008[0.97]
$\Delta P_t \rightarrow \Delta C_t$	7.369 [0.007]	$\Delta P_t \rightarrow \Delta C_t$	14.267[0.00]	$\Delta P_t \rightarrow \Delta C_t$	4.1470[0.04]	$\Delta P_t \rightarrow \Delta C_t$	4.5498[0.03]

Panel B: Residual diagnostics

	Transatlantic		Fronthaul		Transpacific		Backhaul	
	ΔC_t	ΔP_t	ΔC_t	ΔP_t	ΔC_t	ΔP_t	ΔC_t	ΔP_t
J-B test	6351 [0.00]	739 [0.00]	2152 [0.00]	5551 [0.00]	2456.8 [0.00]	802 [0.00]	1325 [0.00]	3089 [0.00]
$Q(36)$	72.25 [0.01]	40.17 [0.33]	63.18 [0.01]	44.03 [0.17]	50.83 [0.05]	49.1 [0.07]	71.76 [0.01]	52.41 [0.05]
$Q^2(36)$	86.90 [0.00]	238.9 [0.00]	207.3 [0.00]	294.4 [0.00]	314.28 [0.00]	138 [0.00]	287.1 [0.00]	121.2 [0.00]
$\overline{R}^2$	0.639	0.685	0.602	0.599	0.628	0.682	0.624	0.633

Notes: All variables are transformed in natural logarithms.

- * and ** indicate significance at the 10% and 5% level, respectively.
- Figures in parentheses (.) and in squared brackets [·] indicate t-statistics and exact significance levels, respectively.
- t-statistics of the estimated coefficients are adjusted using the White (1980) heteroskedasticity consistent variance-covariance matrix, in the cases of heteroskedasticity in the residuals.
- Q(36) and $Q^2(36)$ are the Ljung and Box (1978) Q statistics on the first 36 lags of the sample autocorrelation function of the raw series and of the squared series; these tests are distributed as $\chi^2(36)$. The critical values are 58.11 and 51.48 for the 1% and 5% levels, respectively.
- J-B is the Jarque-Bera (1980) test for normality, distributed as $\chi^2(2)$.

Table 4.15: Estimates of the VECM-SURE for Capesize and Panamax prices on four major routes (2003.1.2-2008.8.29）

$$\Delta C_t = \sum_{i=1}^{p-1} a_{c,i}\Delta C_{t-i} + \sum_{i=1}^{p-1} b_{c,i}\Delta P_{t-i} + w_c Z_{t-1} + \varepsilon_{c,t}$$

$$\Delta P_t = \sum_{i=1}^{p-1} a_{p,i}\Delta C_{t-i} + \sum_{i=1}^{p-1} b_{p,i}\Delta P_{t-i} + w_p Z_{t-1} + \varepsilon_{p,t},\ \varepsilon_t = \begin{pmatrix}\varepsilon_{c,i}\\ \varepsilon_{p,i}\end{pmatrix}\Big|\,\Omega_{t-1}\sim distr(0, H_t)$$

Panel A: VECM-SURE model estimates

Transatlantic				Fronthaul				Transpacific				Backhaul			
ΔC_t		ΔP_t		ΔC_t		ΔP_t		ΔC_t		ΔP_t		ΔC_t		ΔP_t	
w_c	-0.012* (-2.376)	w_p	0.0081* (3.4924)	w_c	-0.0065* (-2.037)	w_p	0.0080* (3.8245)	w_c	-0.0169* (-4.6049)	w_p	0.0089* (3.0682)	w_c	-0.0086* (-3.385)	w_p	0.0051* (2.7489)
$a_{c,1}$	0.7485* (9.4081)	$a_{p,1}$	0.1139* (4.1983)	$a_{c,1}$	0.9055* (17.741)	$a_{p,1}$	0.1475* (6.0807)	$a_{c,1}$	0.7859* (11.311)	$a_{p,1}$	0.0624* (3.0288)	$a_{c,1}$	0.8626* (32.128)	$a_{p,1}$	0.06907* (3.5209)
$a_{c,2}$	-0.1044 (-2.269)	$a_{p,2}$	-0.0609* (-2.549)	$a_{c,2}$	-0.2529* (-6.321)	$a_{p,2}$	-0.1032* (-4.280)	$a_{c,2}$	-0.1577* (-2.8395)	$a_{p,2}$	-0.0223 (-1.040)	$a_{c,2}$	-0.2222* (-8.159)	$a_{p,2}$	-0.0212 (-1.0632)
$a_{c,4}$	-	$a_{p,4}$	-	$a_{c,5}$	-	$a_{p,5}$	0.01736 (1.064)								
$b_{c,1}$	0.2336* (4.0248)	$b_{p,1}$	0.9424* (21.556)	$b_{c,1}$	0.1493* (3.59)	$b_{p,1}$	0.9805* (27.294)	$b_{c,1}$	0.1815* (3.8639)	$b_{p,1}$	1.0501* (25.544)	$b_{c,1}$	0.1396* (3.8178)	$b_{p,1}$	1.0023* (37.521)
$b_{c,2}$	-0.162* (-2.865)	$b_{p,2}$	-0.2075* (-4.711)	$b_{c,2}$	-0.080** (-1.850)	$b_{p,2}$	-0.2471* (-7.666)	$b_{c,2}$	-0.1009* (-2.1518)	$b_{p,2}$	-0.2964* (-7.738)	$b_{c,2}$	-0.0771* (-2.109)	$b_{p,2}$	-0.2556* (-9.5719)
$b_{c,4}$	0.0624** (1.7036)	$b_{p,4}$	-0.0473* (-2.081)	$b_{c,5}$	0.0423* (2.006)	$b_{p,5}$	-0.0527* (-2.624)								
Causality test		Statistics		Causality test		Statistics		Causality test		Statistics		Causality test		Statistics	
$\Delta C_t \rightarrow \Delta P_t$		21.87[0.00]		$\Delta C_t \rightarrow \Delta P_t$		24.51[0.00]		$\Delta C_t \rightarrow \Delta P_t$		7.1317[0.00]		$\Delta C_t \rightarrow \Delta P_t$		8.1699[0.00]	
$\Delta P_t \rightarrow \Delta C_t$		13.86[0.00]		$\Delta P_t \rightarrow \Delta C_t$		8.7928[0.00]		$\Delta P_t \rightarrow \Delta C_t$		11.248[0.00]		$\Delta P_t \rightarrow \Delta C_t$		8.3714[0.00]	

Panel B: Residual diagnostics

	Transatlantic				Fronthaul				Transpacific				Backhaul			
	ΔC_t		ΔP_t		ΔC_t		ΔP_t		ΔC_t		ΔP_t		ΔC_t		ΔP_t	
J-B test	17002	[0.00]	1719	[0.00]	3075	[0.00]	683.2	[0.00]	48009	[0.00]	840	[0.00]	5270	[0.00]	3798	[0.00]
$Q(36)$	33.80	[0.57]	42.24	[0.22]	30.48	[0.73]	43.98	[0.17]	44.77	[0.15]	45.5	[0.13]	48.8	[0.075]	48.79	[0.08]
$Q^2(36)$	375.8	[0.00]	227.4	[0.00]	201.9	[0.00]	210.8	[0.00]	113.1	[0.00]	317	[0.00]	349.1	[0.00]	295.2	[0.00]
$\bar{R}^2$	0.577		0.679		0.598		0.70		0.523		0.715		0.564		0.696	

See notes to Table 4.14.

The findings of cointegration and a two-way feedback causal relationship between both prices can also be explained by the economic conditions and different market features during the second sub-period. On the one hand, the world economy grew rapidly and strongly from 2003 till 2007. Thanks to the sound growth of the world economy, world seaborne trade saw consecutive annual increases, especially for shipments of the main bulk commodities. The huge demand for raw materials is the underlying factor causing these interactions of both prices. On the other hand, stimulated by the booming market, quite a few new investors entered the dry bulk market and many new Capesize and Panamax vessels have been built by either new or old investors. For example, figures from Clarksons Research Studies (2008) reveal that the Capesize fleet expanded from 542 vessels in 2003 to 816 vessels in 2008, roughly a 50% increase during the second sub-period, compared to approximately a 10% growth rate during the first sub-period. Therefore, both markets were exposed to the fierce competition and became more volatile and complex during the second sub-period. Under such circumstances, the prices of hauling dry bulk cargoes, caused by the demand-supply imbalances in one market, will influence the other.

The third sub-period

The cointegration relationship between Capesize and Panamax prices is examined during the period from 1st September 2008 to 24th December 2010. Results reveal that both Capesize and Panamax prices are not cointegrated at the 5% significance level for all routes during this sample period. Looking to the dry bulk shipping market since September 2008, market conditions are significantly different with those over the last two sub-periods. Extreme volatility and unpredictability permeate the weak market. This can be partly attributed to the active participation of three big iron ore miners (Vale, BHP Billiton and Rio Tinto) in the shipping market, as well as the speculation before and during the annual iron ore pricing talks, both of which may have increased the volatility of daily time charter rates, in particular the rates for long-haul iron ore transportation.

Under such circumstances, the dynamics between the two markets may be affected. For instance, on the transpacific route, the ratio of Capesize versus Panamax tonnage dropped to 0.20 in November 2008 and soared to 8.0 in January 2009. Over the second sub-period analysed herein, however, it just moved within the range of 1.35 to 3.5. Furthermore, the Capesize market is mainly determined by iron ore seaborne trade, while the Panamax market is influenced by not only iron ore, but also the coal and grain seaborne trade. During the weak market when there is no enough iron ore demand, the Capesize market becomes very sluggish, while Panamax vessels can be used for grain and coal transportation. Subsequently, these two ship markets react to market information in different way and make these two price series deviate each other.

4.3.3.2. The dynamic relationships between volatilities

Having investigated the interrelationship in returns between both markets, the relationship in the variance is now examined. During the first sub-period, there are no spillovers between volatilities in both markets, due to market troughs during most of the time from 1999 to 2002 (results are not reported here, but are available from the authors). The finding of no volatility spillovers is found over the third sub-period as well due to no significant cointegration relationship between Capesize and Panamax prices.

During the second sub-period, the dynamic relationships between both prices are investigated by employing the ECM-GARCH models. The equations in the models are estimated separately and the results are reported in Table 4.16. Preliminary evidence on the series with the Student-t distribution reveals that the number of degrees of freedom, v, is lower than 4 for all the Capesize cases and one of the Panamax routes (v=3.02, v=3.34, v=2.61 and v=3.72 in the fronthaul, the transpacific, the transatlantic and in the backhaul routes for Capesize, v =3.93 in the transpacific route for Panamax). Thus, the QMLE is employed in the estimation of the ECM-GARCH models for all four Capesize routes and for the transpacific route for Panamax. For the Panamax variance equations, MLE is used to estimate parameters with the assumption that residuals follow a student-t distribution.

Panel C in Table 4.16 reports diagnostic tests on the standardized residuals. Ljung and Box (1978) statistics for 36th-order serial correlation in level and the squared standardized residuals, suggest that a null hypothesis of autocorrelation and heteroskedasticity should be rejected. The ARCH LM of Engle (1982) tests also indicate that there are no ARCH effects for all residual series. The estimated kurtosis indicates the presence of excess kurtosis in the residuals on all investigated routes. Therefore, the Jarque and Bera (1980) test rejects normality for all routes. The persistence of volatility of Capesize and Panamax prices, measured by $a_{ii} + g_{ii}$, shows that the unconditional variances are stationary on all routes.

It can be seen that in the variance equations, the coefficients of the lagged variance and the lagged error terms are statistically significant, indicating the ARCH effects for both Capesize and Panamax prices for the four routes and the volatilities of both prices are all time-varying. The coefficients of volatility spillover effects, $d2_{c,1}$ and $d1_{p,1}$ are, respectively, the lagged squared residuals of the Panamax mean equation in explaining the volatility of Capesize rates, and of the Capesize mean equation in explaining the volatility of Panamax rates.

For the transatlantic route, the coefficients of both the lagged error terms and the lagged variance in the Capesize variance equation are higher than those in the Panamax variance equation, implying both the past shocks (new information) and the past volatilities (old information) have greater impact on the volatility of the Capesize market. The coefficients of the volatility spillovers from the Capesize market to the Panamax market (0.0425) and from the Panamax to the Capesize (0.1818) are both significant at the 5% level, which implies that there are bidirectional volatility spillovers between both markets. However, it seems stronger from the Panamax to the Capesize, which is in accordance with earlier results that the Capesize market informationally leads the Panamax market. More specifically, when prices for Capesize vessels are high enough, charterers will consider hiring two Panamax vessels to substitute for one Capesize, when they find it profiTable to do so. In addition, during the weak Capesize market and/or a relatively strong Panamax market, there might be occasions when shipowners would accept part cargoes of the Panamax market. The spillovers from the Panamax to the Capesize are only found in the transatlantic area, mainly attribuTable to the more active trading activity of Panamax vessels compared to Capesize vessels in this area.

In the fronthaul route, the results show that past shocks (new information) have a greater impact on Capesize prices rather on Panamax prices, while the past variance (old information) is used more by the market players in the Panamax segment. The coefficients of the 21st lagged error terms in the Capesize variance are significant, implying that the shocks one month ago can still influence the market volatility. With respect to spillover effects, it can be seen that the coefficient of the volatility spillover from the Capesize to the Panamax market is significant (0.0236), while the parameter from the Panamax to the Capesize market is not significant at the conventional levels, indicating that there is a unidirectional volatility spillover from the Capesize to the Panamax sector. In the transpacific route, the results indicate that the Capesize market plays a leading role in incorporating new information and a volatility spillover from the Capesize to the Panamax market is significantly demonstrated at the 5% level, while the volatility from the Panamax to the Capesize market (0.021) is not significant at the conventional levels.

Table 4.16: Estimates of the ECM-GARCH-X for Capesize and Panamax prices on four major routes (2003.1.2-2008.8.29）

$$\Delta C_t = \sum_{i=1}^{p-1} a_{c,i}\Delta C_{t-i} + \sum_{i=1}^{p-1} b_{c,i}\Delta P_{t-i} + w_c Z_{t-1} + \varepsilon_{c,t}$$

$$\Delta P_t = \sum_{i=1}^{p-1} a_{p,i}\Delta C_{t-i} + \sum_{i=1}^{p-1} b_{p,i}\Delta P_{t-i} + w_p Z_{t-1} + \varepsilon_{p,t},\ \varepsilon_t = \begin{pmatrix}\varepsilon_{c,i}\\ \varepsilon_{p,i}\end{pmatrix}\Big|\,\Omega_{t-1} \sim distr(0, H_t)$$

$$H_t = C'C + A'\varepsilon_{t-1}\varepsilon'_{t-1}A + G'H_{t-1}G + D1'e_{1,t-1}e'_{1,t-1}D1 + D2'e_{2,t-1}e'_{2,t-1}D2$$

Transatlantic				Fronthaul				Transpacific				Backhaul			
ΔC_t		ΔP_t		ΔC_t		ΔP_t		ΔC_t		ΔP_t		ΔC_t		ΔP_t	
Panel A: Conditional mean estimates															
w_c	-0.0053* (-2.0933)	w_p	0.0038* (2.3386)	w_c	-0.0035* (-2.1505)	w_p	0.0034* (2.2329)	w_c	-0.0155* (-3.3086)	w_p	0.0071* (2.9079)	w_c	-0.003** (-1.6739)	w_p	0.0021* (1.6676)
$a_{c,1}$	0.8752* (23.7552)	$a_{p,1}$	0.1027* (5.5757)	$a_{c,1}$	1.0041* (27.223)	$a_{p,1}$	0.1162* (6.7923)	$a_{c,1}$	0.8789* (21.657)	$a_{p,1}$	0.0587* (4.1298)	$a_{c,1}$	0.9640* (30.6532)	$a_{p,1}$	0.0867* (4.6317)
$a_{c,2}$	-0.1439* (-3.6644)	$a_{p,2}$	-0.0567* (-3.0519)	$a_{c,2}$	-0.2915* (-9.8499)	$a_{p,2}$	-0.0713* (-3.8535)	$a_{c,2}$	-0.2010* (-5.2910)	$a_{p,2}$	-	$a_{c,2}$	-0.2552* (-8.1162)	$a_{p,2}$	-0.0439* (-2.2991)
$a_{c,4}$	-0.0497 (-1.6299)	$a_{p,4}$	-	$a_{c,5}$	-	$a_{p,5}$	-								
$b_{c,1}$	0.2029* (4.9546)	$b_{p,1}$	1.0029* (33.2526)	$b_{c,1}$	0.1559* (4.5929)	$b_{p,1}$	0.9755* (33.052)	$b_{c,1}$	0.1688* (4.9954)	$b_{p,1}$	1.0516* (28.6267	$b_{c,1}$	0.1485* (4.9829)	$b_{p,1}$	1.0732* (31.2845)
$b_{c,2}$	-0.1293* (-3.0635)	$b_{p,2}$	-0.2321* (-7.0977)	$b_{c,2}$	-0.0642** (-1.8566)	$b_{p,2}$	-0.2304* (-7.78)	$b_{c,2}$	-0.1197* (-3.1983)	$b_{p,2}$	-0.3024* (-8.0997)	$b_{c,2}$	-0.0899* (-3.1583)	$b_{p,2}$	-0.3026* (-8.3605)
$b_{c,4}$	0.0525** (1.8540)	$b_{p,4}$	-0.0366* (-2.0772)	$b_{c,5}$	0.0286** (1.8449)	$b_{p,5}$	-0.035* (-2.499)								
Panel B: Conditional variance estimates															
c_1	1.5E-05* (2.836)	c_2	1.46E-05* (4.7089)	c_1	3.28E-05* (4.2439)	c_2	1.5E-05* (4.4197)	c_1	6.81E-06* (1.955)	c_2	5.4E-05* (2.6222)	c_1	2.2E-05* (3.7999)	c_2	6.8E-06* (2.5284)
$a_{c,1}$	0.4553* (5.4047)	$a_{p,1}$	0.3648* (6.0118)	$a_{c,1}$	0.4876* (5.7735)	$a_{p,1}$	0.3649* (5.6943)	$a_{c,1}$	0.1852* (4.5114)	$a_{p,1}$	0.1742* (4.6874)	$a_{c,1}$	0.3470* (6.6308)	$a_{p,1}$	0.2057* (4.2202)
-	-	-	-	$a_{c,21}$	0.1132* (2.8111)	-	-	-	-	-	-	-	-	-	-
$g_{c,1}$	0.5213* (9.5689)	$g_{p,1}$	0.4939* (9.4336)	$g_{c,1}$	0.2919* (4.3467)	$g_{p,1}$	0.5237* (9.4354)	$g_{c,1}$	0.7834* (21.9494)	$g_{p,1}$	0.7889* (23.572)	$g_{c,1}$	0.6407* (14.47)	$g_{p,1}$	0.7615* (15.5945)
$d2_{c,1}$	0.1818* [0.0094]	$d1_{p,1}$	0.0425* [0.0012]	$d2_{c,1}$	0.07 [0.2007]	$d1_{p,1}$	0.0236* [0.0387]	$d2_{c,1}$	0.02120 [0.1972]	$d1_{p,1}$	0.0128* [0.0365]	$d2_{c,1}$	0.0102 [0.5148]	$d1_{p,1}$	0.0078 [0.1282]

Table 4.16: Continued

Panel C: Diagnostic tests on standardized residuals of ECM-GARCH-X models

	Transatlantic		Fronthaul		Transpacific		Backhaul	
	ΔC_t	ΔP_t	ΔC_t	ΔP_t	ΔC_t	ΔP_t	ΔC_t	ΔP_t
J-B normality test	2778.93 [0.000]	604.24 [0.00]	821.65 [0.000]	449.16 [0.000]	2169.7 [0.000]	740.8 [0.000]	1076.8 [0.000]	1561.7 [0.000]
Q(36)	42.038 [0.226]	47.236 [0.100]	42.67 [0.206]	47.70 [0.092]	42.10 [0.224]	40.17 [0.291]	34.76 [0.528]	47.79 [0.09]
$Q^2(36)$	29.237 [0.78]	39.838 [0.303]	33.32 [0.597]	50.32 [0.06]	33.94 [0.566]	20.984 [0.978]	29.41 [0.773]	25.40 [0.91]
ARCH(36)	0.7753 [0.828]	1.0055 [0.4608]	0.9385 [0.5743]	1.321 [0.098]	0.9891 [0.4882]	0.6531 [0.9442]	0.8061 [0.7868]	0.6618 [0.939]
Persistence ($a_{ii} + g_{ii}$)	0.9766	0.858	0.892	0.887	0.968	0.963	0.9876	0.967
Log-likelihood	4015.36	4567.57	4171.23	4642.9	3364.4	3790.27	3910.76	4304
AIC	-5.6559	-6.4358	-5.9602	-6.5423	-5.2841	-5.9569	-5.5109	-6.071
SBIC	-5.6406	-6.4206	-5.9189	-6.527	-5.2704	-5.9448	-5.4776	-6.058

Notes:

- ** and * indicate significance at the 10% and 5% level, respectively.
- Figures in parentheses (.) and in squared brackets [·] indicate t-statistics and exact significance levels, respectively.
- Volatility spillover effects are measured by the coefficients of the d1 and d2.
- J-B Normality is the Jarque and Bera (1980) normality test, with probability values in square brackets.
- $Q(36)$ and $Q^2(36)$ are the Ljung and Box (1978) tests for 36th order serial correlation and heteroskedasticity in the standardized residuals and in the standardized squared residuals, respectively.
- ARCH(36) is the Engle's (1982) F test for Autoregressive Conditional Heteroskedasticity.
- The persistence coefficient is calculated as $a_{ii} + g_{ii}$

The finding of unidirectional spillover effects in both fronthaul and transpacific routes can be explained by the fact that the Capesize market is more sensitive to news than the Panamax market, due to the limited number of ports and trades at which larger vessels operate. It is usually the case that Panamax vessels are attracted into the Capesize market to be substitutes during booms in the Capesize market. Alternatively, Capesize vessels will participate in the Panamax segment and accept part cargoes when this is found to be more profitable. While Panamax vessels are more flexible in operation and are used to carry more cargoes than Capesize vessels, so shocks to the Panamax market may be absorbed by participating in the transportation of other cargoes or in other trading routes.

In the backhaul route, the coefficient of the lagged error terms in the Capesize variance is higher than that in the Panamax variance equation, implying that past shocks have a greater impact on Capesize than Panamax volatility. On the other hand, the coefficient of the lagged variance in the Capesize variance equation is lower than that in the Panamax variance equation, implying that market agents make more use of old information in the Panamax market. The coefficients of the volatility spillovers in either market are not significant at the conventional levels, implying that there is no strong evidence for the volatility spillovers in either direction. The result that there are no volatility spillovers in any direction at the conventional significance levels may be justified by the thin trading in this investigated route, which is recognized as the one with lowest trading volume among all. Due to the low trading activity, shocks to this route may be absorbed by participating in other trading areas, but not by transmitting them onto smaller vessels. Overall, the interrelationship in both returns and volatilities between the two markets during the two sub-periods is clearly illustrated in Table 4.17.

Table 4.17: Summary of interrelationship in terms of returns and volatilities between Capesize and Panamax prices on four routes during two sub-periods

	The first sub-period(1999-2002)				*The second sub-period(2003-2008)*			
	Prices		Volatilities		Prices		Volatilities	
	Cape	Panamax	Cape	Panamax	Cape	Panamax	Cape	Panamax
Transatlantic	⇢ ←		-----		→ ←		→ ←	
Fronthaul	⇢ ←		-----		→ ←		→ ⇠	
Transpacific	⇢ ←		-----		→ ←		→ ⇠	
Backhaul	⇢ ←		-----		→ ←		⇢	

Notes: A dashed arrow indicates the relationship in one direction is not significant at the conventional levels. A solid arrow implies the relationship in one direction is significant at the 5% level. A dashed line means no volatility spillovers in any direction.

4.3.4. Dynamic relationships between Panamax and Handymax sub-markets

The methodology applied in the section 4.3.3 is employed in this part as well to examine the dynamic relationships between Panamax and Handymax markets, including the cointegration tests and the investigation on the short-run and long-run relationships between Panamax and Handymax prices.

Cointegration between Panamax and Handymax sub-markets

Having identified that daily time charter rates are all $I(1)$ variables, the Johansen (1988) procedure is employed in order to test for cointegration between Panamax and Handymax prices for all routes. The Schwarz Bayesian Information Criterion (Schwarz, 1978), Akaike Information Criterion (Akaike, 1973) and LR test were used to determine the lag length in the models during the sub-periods. The results of the cointegration test are presented in the Table 4.18.

During the first sub-period, the estimated $\lambda_{\max}$ and λ_{trace} statistics show that there exists no cointegrating relationship between Panamax and Handymax prices at the 5% significance level, which may result from the low trading volume during this period. When there is no enough trading volume, shipbrokers may provide rates arbitrarily, so that Panamax and Handymax prices may not follow closely, creating a deviation in their long-run relationship.

During the second sub-period(Ⅰ) for Handymax, the cointegrating relationship is found at the 5% significance level at the fronthaul and transpacific routes without the backhaul, and during the second sub-period (Ⅱ) for Supramax, the cointegrating relationship exists at the conventional significance levels at all routes. During the third sub-period, both Panamax and Supramax prices are significantly cointegrated at the fronthaul and transpacific routes without the backhaul one. The shipping demand for grain and coal is the underlying fundamental for the cointegration relationship between these two markets.

In order to investigate the short-run properties of Panamax and the Handymax prices, we examine the estimated error correction coefficients of Panamax prices α_1 and of Handymax prices α_2. The estimates are provided in Table 4.19. It can be seen that the error correction coefficient of Panamax prices α_1 is statistically insignificant, whereas that of Handymax prices α_2 is positive and significant for all cases, with the exception of Panamax prices at the transpacific route during the third sub-period. Hence it is only the Handymax market that corrects previous deviations from the long run equilibrium. This means that past errors affect current forecasts of the underlying Handymax prices, but not Panamax prices themselves. The Granger causality tests also reveal that there is a unidirectional causal relationship at the 5% significant level between the Panamax and the Handymax market for all cases. It implies only Panamax prices granger cause Handymax prices without the feedback effects.

The findings regarding error correction coefficients and granger causality test are expected and may be explained by the trading patterns of each market. The Panamax market is mainly involved in four trading routes to transport main bulk cargoes, such as iron ore, coal and grain, while the Handymax sector operates in a large number of geographically dispersed global trades, mainly carrying grain, coal and minor bulks including steel products, forest products and fertilizers. Consequently changes in the Panamax market will have a direct impact on the Handymax sector caused by changes in trading volume of main bulk cargoes, while changes in the Handymax market will not have a feedback effect on the Panamax, because it may be caused by changes of minor bulks.

Table 4.18: Johansen (1988) tests for the number of cointegrating vectors between Panamax and Handymax prices

	Lags	*Hypothesis (maximal)*		*Test statistic*	*Hypothesis (trace)*		*Test statistic*	95% Critical values	
		H_0	H_1	$\lambda_{\max}$	H_0	H_1	λ_{trace}	$\lambda_{\max}$	λ_{trace}
Period One									
FH	3	$r=0$	$r=1$	5.145	$r=0$	$r=1$	7.026	15.892	20.262
		$r\le1$	$r=2$	1.881	$r\le1$	$r=2$	1.881	9.165	9.165
TP	3	$r=0$	$r=1$	15.649	$r=0$	$r=1$	16.648	15.892	20.262
		$r\le1$	$r=2$	0.998	$r\le1$	$r=2$	0.998	9.165	9.165
BH	3	$r=0$	$r=1$	17.259	$r=0$	$r=1$	19.047	15.892	20.262
		$r\le1$	$r=2$	1.789	$r\le1$	$r=2$	1.789	9.165	9.165
Period Two Ⅰ for Handymax									
FH	2	$r=0$	$r=1$	27.706	$r=0$	$r=1$	32.749	15.892	20.262
		$r\le1$	$r=2$	5.043	$r\le1$	$r=2$	5.043	9.165	9.165
TP	2	$r=0$	$r=1$	17.460	$r=0$	$r=1$	21.971	15.892	20.262
		$r\le1$	$r=2$	4.510	$r\le1$	$r=2$	4.510	9.165	9.165
BH	2	$r=0$	$r=1$	12.436	$r=0$	$r=1$	16.583	15.892	20.262
		$r\le1$	$r=2$	4.147	$r\le1$	$r=2$	4.147	9.165	9.165
Period Two Ⅱ for Supramax									
FH	2	$r=0$	$r=1$	53.138	$r=0$	$r=1$	55.747	15.892	20.262
		$r\le1$	$r=2$	2.609	$r\le1$	$r=2$	2.609	9.165	9.165
TP	2	$r=0$	$r=1$	23.689	$r=0$	$r=1$	27.115	15.892	20.262
		$r\le1$	$r=2$	3.426	$r\le1$	$r=2$	3.426	9.165	9.165
BH	2	$r=0$	$r=1$	21.771	$r=0$	$r=1$	25.962	15.892	20.262
		$r\le1$	$r=2$	4.191	$r\le1$	$r=2$	4.191	9.165	9.165
Period Three									
FH	2,5	$r=0$	$r=1$	19.931	$r=0$	$r=1$	25.879	15.892	20.262
		$r\le1$	$r=2$	5.948	$r\le1$	$r=2$	5.948	9.165	9.165
TP	2,8	$r=0$	$r=1$	37.577	$r=0$	$r=1$	42.901	15.892	20.262
		$r\le1$	$r=2$	5.323	$r\le1$	$r=2$	5.323	9.165	9.165
BH	2,5	$r=0$	$r=1$	14.623	$r=0$	$r=1$	19.939	15.892	20.262
		$r\le1$	$r=2$	5.316	$r\le1$	$r=2$	5.316	9.165	9.165

Notes:

- TA, FH, TP and BH refer to the transatlantic, the fronthaul, the transpacific and the backhaul route, respectively.
- Lags is the lag length of a VAR model; the lag length is determined using the SBIC (Schwarz, 1978), AIC (Akaike, 1973) and LR tests.
- r represents the number of cointegrating vectors, $\lambda_{\max}(r,r+1)=-T\ln(1-\hat{\lambda}_{r+1})$ and $\lambda_{trace}(r)=-T\sum_{i=r+1}^{n}\ln(1-\hat{\lambda}_i)$ where $\hat{\lambda}_i$ are the estimated eigenvalues of the $\prod$ matrix in Eq.(1). Critical values are from Osterwald-Lenum (1992), Table1.
- Estimates of the coefficients in the cointegrating vector are normalized with respect to the coefficient of the Panamax. The statistic for the parameter restrictions on the coefficients of the cointegrating vector is $-T[\ln(1-\hat{\lambda}_1*)-\ln(1-\hat{\lambda}_1)]$ where $\hat{\lambda}_1*$ and $\hat{\lambda}_1$ denote the largest eigenvalues of the restricted and the unrestricted models, respectively.

Table 4.19: Estimates of error correction coefficients and Granger causality between Panamax and Handymax markets

$$\begin{pmatrix}\Delta TCP_t\\ \Delta TCH_t\end{pmatrix}=\sum_{i=1}^{p}\Gamma_i\begin{pmatrix}\Delta TCP_{t-i}\\ \Delta TCH_{t-i}\end{pmatrix}+\begin{pmatrix}\alpha_1\\ \alpha_2\end{pmatrix}\begin{pmatrix}1 & \beta_1 & \beta_2\end{pmatrix}\begin{pmatrix}TCP_{t-1}\\ 1\\ TCH_{t-1}\end{pmatrix}+\begin{pmatrix}\varepsilon_{pt}\\ \varepsilon_{ht}\end{pmatrix},\begin{pmatrix}\varepsilon_{pt}\\ \varepsilon_{ht}\end{pmatrix}\sim iid(0,\Sigma)$$

Routes	Lags	Coefficients Estimates		Cointegrating vector	Granger Causality	
		α_1	α_2	$\beta' = (1\ \beta_1\ \beta_2)$	$\Delta TCP_t \rightarrow \Delta TCH_t$	$\Delta TCH_t \rightarrow \Delta TCP_t$
Period Two Ⅰ						
FH	2	-0.0004 (-0.119)	0.007** (5.237)	(1,1.048,-1.116)	42.971[0.00]	5.752[0.06]
TP	2	-0.007 (-1.581)	0.006** (3.158)	(1,1.608,-1.187)	72.746[0.00]	2.496[0.083]
Period Two Ⅱ						
FH	2	-0.003 (-0.584)	0.013** (7.232)	(1,0.78,-1.089)	38.513[0.00]	0.989[0.607]
TP	2	-0.005 (-1.068)	0.012** (4.278)	(1,3.392,-1.336)	46.522[0.00]	4.312[0.116]
BH	2	-0.002 (-0.771)	0.009** (4.275)	(1,4.797,-1.464)	53.726[0.00]	2.845[0.241]
Period Three						
FH	2,5	-0.007 (-1.485)	0.0146** (3.978)	(1,-0.416,-0.969)	28.097[0.00]	6.775[0.08]
TP	2,8	-0.029** (-3.876)	0.016** (3.951)	(1,-1.220,1.976)	46.803[0.00]	5.436[0.142]

Notes:

- ΔTCP_t means changes in daily time charter rates for the Panamax, ΔTCH_t means changes in daily time charter rates for the Handymax.
- [·] in the left side of the Granger Causality column indicates the exact significance level of the rejection of the hypothesis that Panamax prices do not granger causality Handymax ones; [·] in the right side indicates the significance level of the rejection of the hypothesis that Handymax prices do not granger causality Panamax ones

Sub-conclusions

For the Capesize and the Panamax markets, conclusions can be drawn as follows. Firstly, information transmission between the two segments changes over time. During the first sub-period, there is a unidirectional relationship in returns and no volatility spillovers in any direction are found on all routes. However, during the second sub-period, a bi-directional causal relationship in daily returns on all routes implies that both Capesize prices and Panamax prices can be important sources of information and, additionally, that Capesize prices tend to reflect new information more rapidly than Panamax prices. The results, in terms of volatilities, indicate that in the transatlantic route, there is a bi-directional relationship in volatility spillovers and the direction of the information flow seems to be stronger from the Capesize to the Panamax. In the fronthaul and transpacific route, volatilities in the Capesize market are transmitted to the Panamax, while the feedback effect is not significantly demonstrated. In the backhaul, there is no strong evidence of volatility spillovers in either market. During the third sub-period, there is no cointegrating relationship between variables at four routes.

In terms of both returns and volatilities, the results have implications for the decision making of market players. Under current market circumstances, informed agents should not be indifferent between the trading activities in the two markets, as information transmits faster in the Capesize than in the Panamax market. Changes in Capesize prices seem to contain useful information about the subsequent changes in Panamax prices.

Secondly, the long-run mean of the $Cape / Pnm$ ratio differs in each route, ranging from 1.7 times to 2.23 times. This ratio contains useful information for both shipowners and charterers. Specifically, when the ratio is greater than its long-run average, charterers may consider splitting one large consignment on a particular route, conventionally carried by a Capesize, into two shipments on Panamax vessels so as to reduce freight costs. At the same time, shipowners may consider reletting Capesize vessels to cover the risk of a possible drop in price subsequently. When the ratio is lower than its long-run mean, shipowners or charterers may consider the risk/return trade-off to make profits or to mitigate risks by switching between the two markets.

Finally, the weighting of each route in both markets changes across time as well. The backhaul route is known for its low trading volume during two sub-periods. Due to a huge demand for raw materials such as iron ore and coal from China and India since 2003, both Capesize and Panamax vessels are now actively involved in the transpacific and fronthaul route. In the transatlantic area, however, shipbrokers find Capesize vessels are less active than before even though Panamax vessels are still active in this area.

For the Panamax and Handymax markets, the information transmission between the two segments changes over time as well. Panamax prices and Handymax prices are not cointegrated during the first sub-period, while they are during the rest of the investigated periods at the fronthaul and the transpacific routes. At the backhaul route, only Panamax and Supramax prices are cointegrated during the second sub-period. Furthermore, no spillover effects in daily volatilities between these two markets are found at the investigated routes.

4.4. Dynamic relationships between the spot freight market and the forward market

The scope of this section is to examine the price discovery properties of dry bulk freight forward prices. This is conducted by testing the unbiasedness hypothesis and the lead-lag relationship between the freight forward and spot rates. The research focuses on the most liquid dry bulk freight forward prices, which are those on the routes C4, C7 and TC average for Capesize vessels, P2A, P3A, and TC average for Panamax vessels, and TC average for Handymax vessels.

4.4.1. The unbiasedness hypothesis of the freight forward prices in the dry bulk market

The relationship between forward prices before maturity and the expected spot prices on the maturity day of the contract has attracted considerable interest and prompted discussion, in particular, the unbiasedness hypothesis, in the shipping futures or forward markets, examples are Chang and Chang(1996), Kavussanos and Nomikos (1999), Kavussanos et al (2001) and Kavussanos and Visvikis (2004) among others. The detailed review on the previous research can be seen in Chapter 3.

This section investigates the unbiasedness hypothesis for the Freight Forward Agreements (FFA) market, and check whether FFA prices before maturity are the unbiased estimators of the realized spot prices on different routes for Capesize, Panamax and Handymax vessels during the period of Jan 2005 to Dec 2010. The counter forward freight agreements were firstly introduced in 1992 and gained increasing popularity, especially since 2002, when the freight forward contract (BIFFEX) stopped trading after its first start in 1985. To test whether the price of a forward contract is the unbiased expectations of the spot price on the delivery date is of importance to market participants. As Kavussanos, Visvikis and Menachof (2004) argue that if there exists a bias in forward prices, it can increase the cost of hedging. And if forward prices fulfill the price discovery role, they may provide accurate forecasts of the realized spot prices and consequently provide new information in the market. Decisions in the physical market are thus facilitated, which can help secure market agents' cash-flow. The investigation of this topic is therefore of great importance, because it may provide a free source of information and shed some insight to whether the forward can be used to guide physical market decisions.

4.4.1.1. To test the unbiasedness hypothesis

Because seaborne freight is a service which is produced while carried out, and the capacity which is not utilized cannot be stored, shipping is a non-storable commodity. Arbitrage between the spot and the forward market is therefore not possible. Hence, the freight forward contract cannot be priced using the cost-of-carry relationship which involves storage of the underlying commodity, see Kavussanos and Nomikos (2003). Prices of the freight forward contract must therefore reflect the aggregated expectations of the market with regards to the underlying spot rates at the time of settlement, see Cullinane (1992). This relationship can be expressed in the following way;

$$F_{t-i,t} = E_{t-i}(S_t) \tag{4.24}$$

where $F_{t-i,t}$ is the price of a forward contract at time $t-i$ with the settlement at time t. $E_{t-i}(S_t)$ is the sum of expectations of all market participants what the spot price will be at time t. They form their expectations on the basis of all available information (market reports, brokers opinions, etc) and their personal evaluation of the forward prices. This pricing relationship is the backbone of the unbiasedness hypothesis, implying that forward prices are unbiased estimators of the underlying forward spot prices.

Because forward prices might include a risk premium, it is not possible to conduct an isolated test of whether the market agents have rational expectations. Test of the unbiasedness hypothesis is therefore a joint test of no risk premium and the rationality of expectations, see Fama (1991). These two cannot be separated without making further assumptions regarding how expectations are formed and the risk preferences of the market agents. If either of these hypotheses is rejected the unbiasedness hypotheses is rejected as well. If the agents would be risk averse then they would ask for a risk premium which could formally be expressed as a constant.

Rational expectations do not mean that market participants can get all information available. It means that the information available at $t-i$ is used efficiently to predict the forward price. The information quantity available at $t-i$ can be very small or quite large, therefore the forecasts can be bad or good. What's important is that there exists no systematic error in the forecasts. In the period prior to maturity $t-i$, new information will probably arise in the market and the forward price will change. As soon as the new information has arisen the forward price should change and correct the error. These shocks are formally modeled through the error term ε_t which should be a white noise.

$$S_t = F_{t-i,t} + \varepsilon_t, \varepsilon_t \sim iid(0,\sigma^2) \tag{4.25}$$

In line with this, the unbiasedness hypothesis has therefore traditionally been tested by the speculative market efficiency test proposed by Fama (1984).

$$S_t = \beta_1 + \beta_2 F_{t-i,t} + \varepsilon_t \tag{4.26}$$

Where S_t is the spot price at period t, $F_{t-i,t}$ is the forward price at time $t-i$ for the delivery at time t and ε_t is a white noise error with zero mean and variance σ^2.

If the forward rate is an unbiased predictor of the spot rate this requires the intercept to be zero and the slope coefficient near to unity. This relationship could easily be verified by testing whether the coefficients are statistically different from $\beta_1 = 0$ and $\beta_2 = 1$ simultaneously. If this is the case, the hypothesis of the unbiasedness is rejected.

Before testing the unbiasedness hypothesis, time series of the investigated prices have to be checked at first to see if they are stationary, because Granger and Newbold (1974) find that the coefficients estimated on the non-stationary time series are inconsistent and their test statistics do not follow standard distributions, leading to invalid inferences and spurious results. A non-stationary time series which can be made stationary after differencing once is therefore often denoted as $I(1)$. If two time series are $I(1)$, any combinations among these two series will also be $I(1)$. There is however one special case where the linear combination of two time-series are $I(0)$ or stationary. In this case, the time series are said to be cointegrated, implying that they cannot drift apart, but return to the long-run equilibrium level. Research on this topic was pioneered by Engle and Granger (1987) and Johansen(1988). The reasoning behind testing for cointegration to test the unbiasedness hypothesis is that if spot and forward prices are $I(1)$, they need to be cointegrated to avoid drifting apart. Cointegration is therefore a necessary condition for the unbiasedness hypothesis to hold.

The following vector error correction modelling (VECM) framework, proposed by Johansen (1988), is used to test for the unbiasedness.

$$\Delta X_t = \mu + \sum_{i=1}^{p-1} \Gamma_i \Delta X_{t-i} + \prod X_{t-1} + \varepsilon_t, \quad \varepsilon_t | \Omega_{t-1} \sim distr(0, H_t) \tag{4.27}$$

Here Δ means the first difference operator, X_t is the $p \times 1$ vector of variables, in our case is 2×1 $(S_t, F_{t-i,t})'$ of log-spot prices and log-freight forward prices, respectively. u is the $p \times 1$ vector of deterministic components, i.e. a linear trend and/or an intercept term, ε_t is a $p \times 1$ vector of error terms, following an as-yet-unspecified conditional distribution with mean zero and time-varying covariance H_t. Γ_i and $\prod$ are coefficient matrices.

4.4.1.2. Description of the data and their statistical properties

As shipping is a service, the underlying target of the FFA trading is not a commodity but a benchmark price. The contracts are cash settled thus there is no physical delivery of a vessel at the end of the period. We concentrate on the routes C4, C7 and TC average for Capesize vessels, P2A, P3A, and TC average for Panamax vessels, and TC average for Handymax vessels. The route definitions can be found in Table 4.20.

FFA and spot prices on each route are obtained from Baltic Exchange during the period of January 2005 to Dec 2010. For the TC average, only FFA figures one month prior to the maturity are available during the period of Sept 2005 to Dec 2010 from Baltic Exchange. There are no FFA figures of two months maturity until Sept 2009 and no FFA prices of three months maturity until April 2010. In consideration of sufficient data for the analysis, only FFA prices with one month maturity are investigated.

As the liquidity in the forward market is found in the nearby contracts, prices of forward contracts of one month, two and three months before maturity are examined. The forward contract with maturity in one month is referred to as the current month contract, while the contract with maturity in two months is denoted as one month contract, and that with maturity in three months is termed as two months contract.

To investigate the unbiasedness hypothesis, FFA prices of the first trading day of each contract, are matched with the settlement price at the contract maturity date. In line with this, three data sets of forward prices (one-month maturity, two-month maturity and three-month maturity) which match the underlying realized spot rates have been generated for each route in each market. The settlement price is calculated as the average of spot prices of the last seven trading days except for the contract of TC average, whose settlement price is calculated as the monthly arithmetic average of spot prices.

In total for routes C4, C7, P2A and P3A, 72 observations for the current month contract, 71 observations for the one month contract and 70 observations for the two months contract, are obtained. For the route 4TC average of the Capesize, 4TC average of the Panamax and 6TC average of the Handymax, 64 observations are available.

Figures 4.8-4.14 present moving patterns of spot and FFA prices on each route. We can see that as expected the difference between the FFA price and the realized spot price becomes larger the longer the maturity of the contract is.

Table 4.20: Route descriptions for each ship size

Type	*Route*	*Route description*	Vessel size (dwt)
Capesize	C2	Tubarao/Rotterdam 160,000 long tons 10 per cent iron ore	160,000
	C3	Tubarao/Qingdao, 160,000 mt 10 per cent iron ore	160,000
	C4	Richards Bay/Rotterdam, 150,000 mt 10 per cent coal	150,000
	C5	W Australia/Qingdao, 160,000 mt 10 per cent iron ore	160,000
	C7	Bolivar/Rotterdam 150,000 mt 10 pct coal	150,000
	C8_03	Delivery Gibraltar-Hamburg range, trans Atlantic round voyage duration 30-45 days, redelivery Gibraltar-Hamburg range.	172,000
	C9_03	Delivery Amsterdam -Rotterdam-Antwerp range or passing Passero, redelivery China-Japan range, duration about 65 days.	172,000
	C10_03	Delivery China-Japan range, round voyage duration 30-40 days, redelivery China-Japan range.	172,000
	C11_03	Delivery China -Japan range, redelivery Amsterdam/Rotterdam /Antwerp range or passing Passero, duration about 65 days.	172,000
Panamax	P1A	A trans Atlantic (including ECSA) round of 45/60 days on the basis of delivery and redelivery Skaw-Gibraltar range.	74,000
	P2A	Basis delivery Skaw -Gibraltar range, for a trip to the Far East, redelivery Taiwan-Japan range, duration 60/65 days.	74,000
	P3A	Pacific round of 35/50 days either via Australia or Pacific, delivery and redelivery Japan/South Korea range.	74,000
	P4	Delivery Japan-South Korea range for a trip via US West Coast-British Columbia range, redelivery Skaw -Gibraltar range, duration 50/60 days.	74,000
Handymax	S1A	Delivery Antwerp/Skaw range for a trip of 60/65 days redelivery Singapore/Japan range including China	52,000
	S1B	Delivery passing Canakkale for a trip of 50/55 days redelivery Singapore/Japan range including China	52,000
	S2	Delivery South Korea/Japan range for 1 Australian or trans Pacific round voyage, for a 35/40 day trip, redelivery South Korea/Japan range	52,000
	S3	Delivery South Korea/Japa range for a trip of 60/65 days redelivery Gibraltar/Skaw range	52,000
	S41	Delivery US Gulf for a trip about 30 days, redelivery Skaw/Passero range,	52,000
	S4B	Delivery Skaw/Passero range for a trip about 30 days, redelivery US Gulf	52,000

Source: Baltic Exchange(2010)

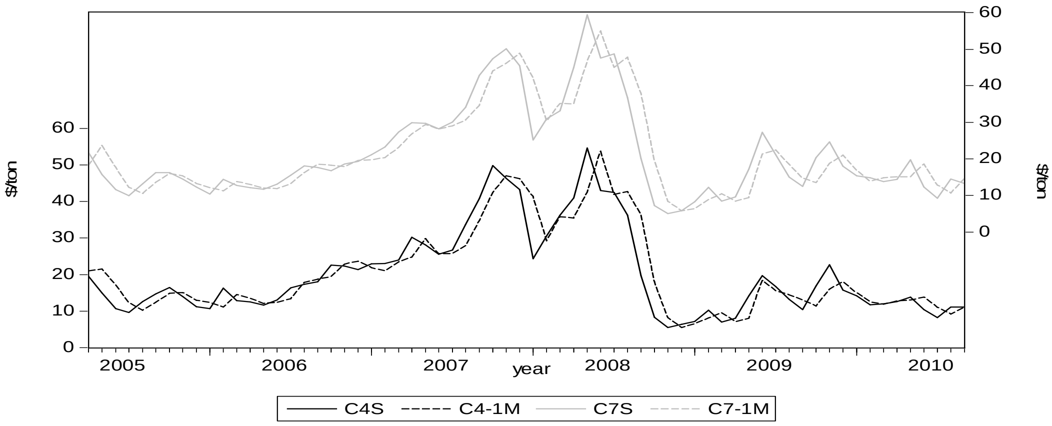

Figure 4.8: Spot freight rates(C4S, C7S) and one-month FFA prices(C4-1M,C7-1M) for routes C4 and C7

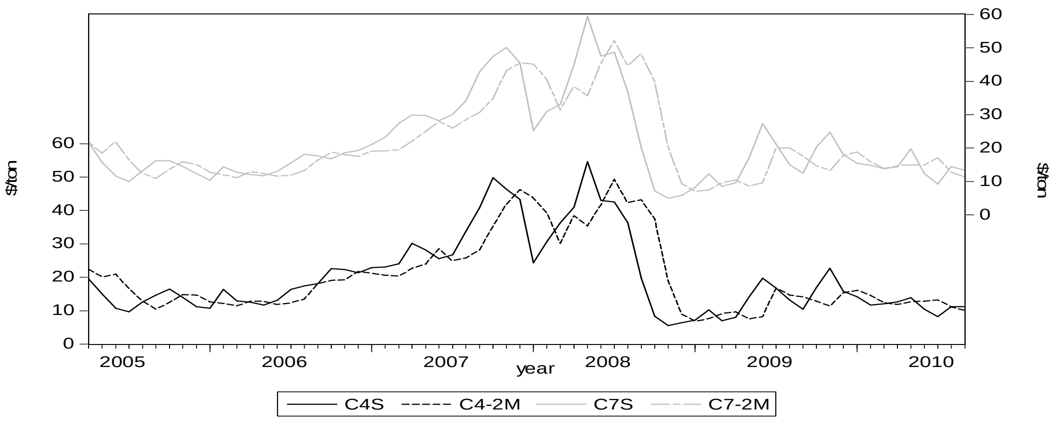

Figure 4.9: Spot freight rates(C4S,C7S) and two-months FFA prices(C4-2M,C7-2M) for routes C4 and C7

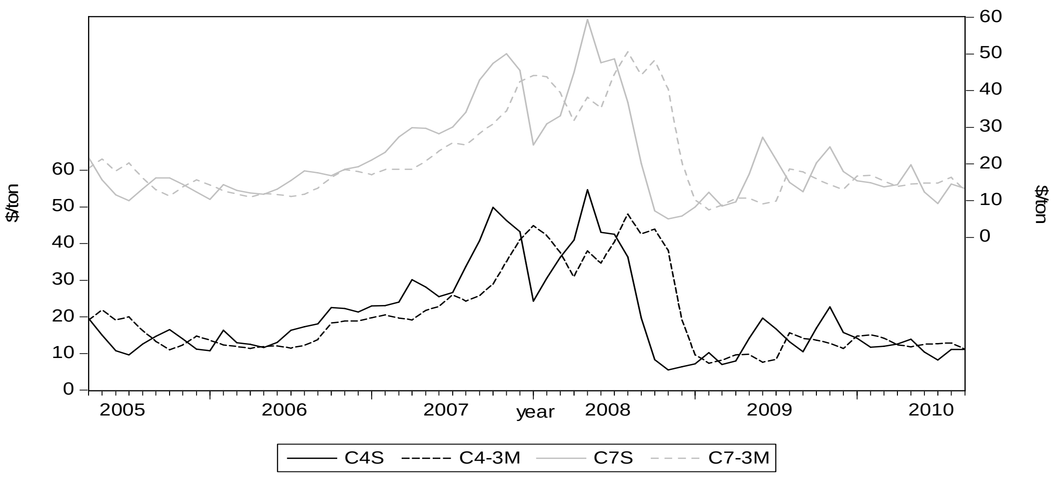

Figure 4.10: Spot freight rates(C4S,C7S) and three-months FFA prices(C4-3M,C7-3M) for routes C4 and C7

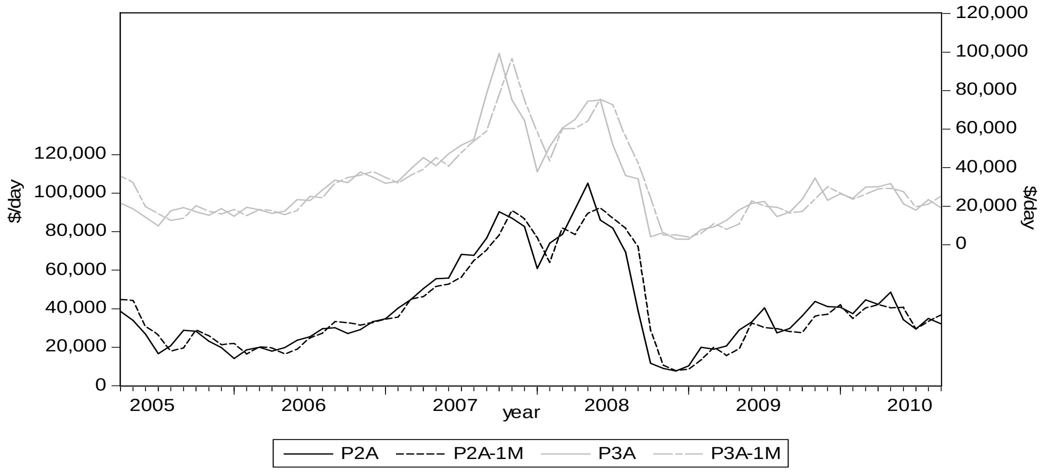

Figure 4.11: Spot time-charter rates (P2A, P3A) and one-month FFA prices(P2A-1M,P3A-1M) for routes P2A and P3A

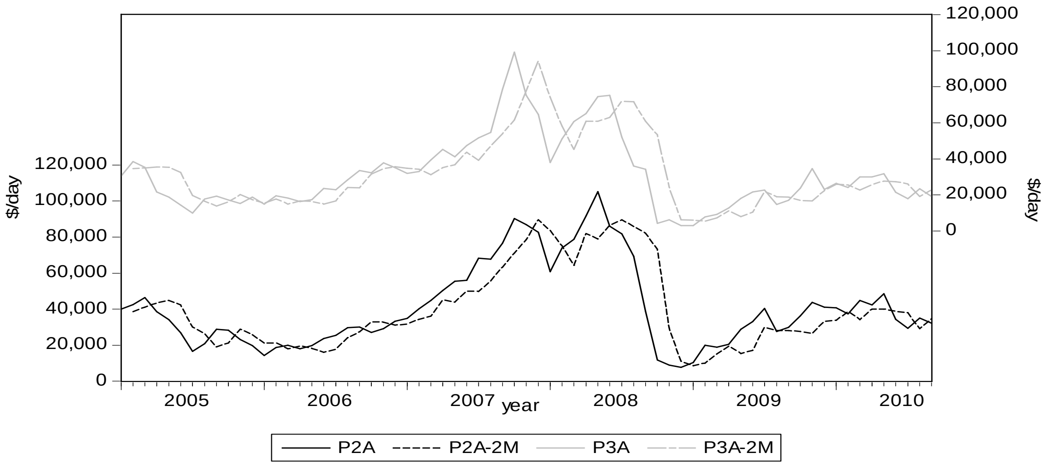

Figure 4.12: Spot time-charter rates(P2A, P3A) and two-months FFA prices(P2A-2M,P3A-2M) for routes P2A and P3A

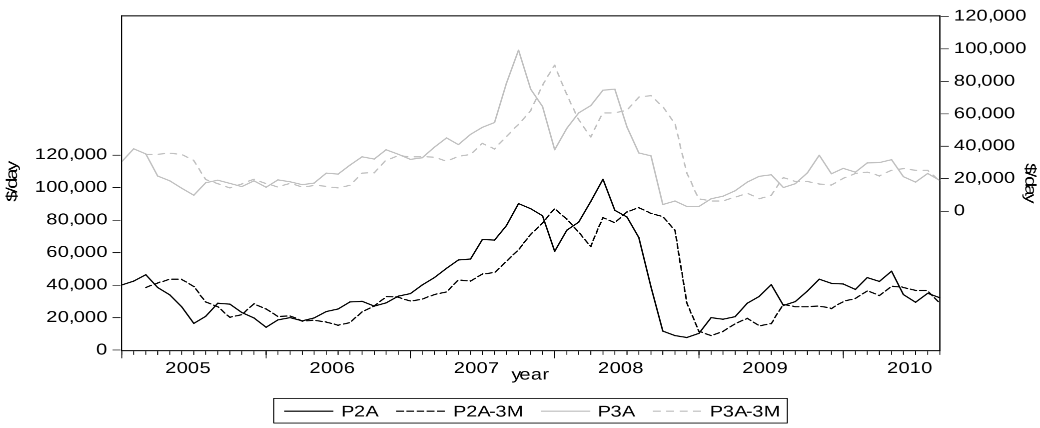

Figure 4.13: Spot time-charter rates(P2A, P3A) and three-months FFA prices(P2A-3M,P3A-3M) for routes P2A and P3A

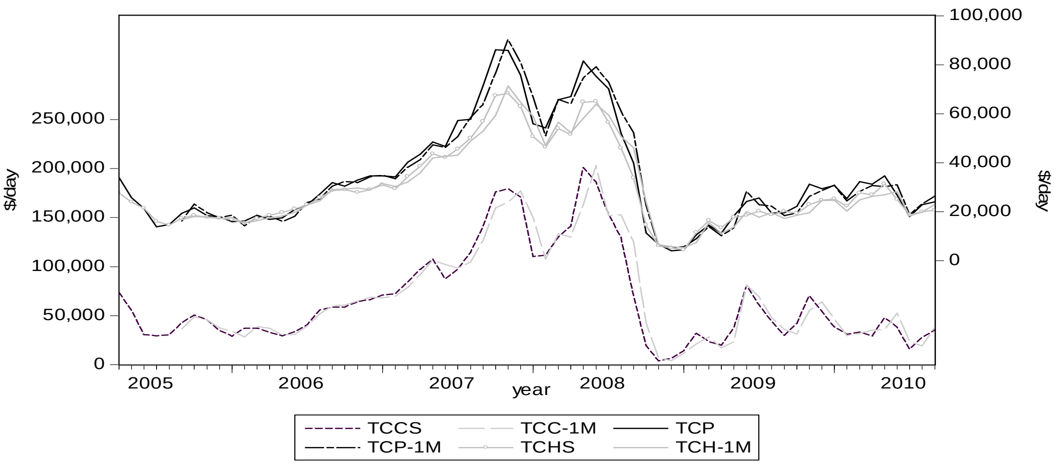

Figure 4.14: Spot time-charter rates (TCCS,TCP,TCHS) and one-month FFA prices (TCC-1M, TCP-1M,TCH-1M) for the TC average in three markets

Tables 4.21-23 shows the summary statistics of the logarithmic first differences of the data. The standard deviations are higher for the spot series than the forward series for all routes and maturities, in line with the results of Kavussanos and Nomikos (1999). Because forward prices always reflect the market expectations on the forward changes, they are used to predict the mean levels, not to foresee the peaks or lows of the spot prices. As maturity approaches the accuracy regarding the expectations of the forward spot rates should however improve. Looking at the three-, two- and one-month forward price series, the standard deviation is in fact increasing as the maturity approaches.

Looking at standard deviations at separate routes, it may be observed that the volatility of P3A is generally higher than others for all maturities. While for the TC average, prices in the Capesize market exhibit higher volatilities than those in Panamax and Handymax markets, which are in line with the findings of for instance Kavussanos (1996a, 2003), where it is also found that freight rates of large ships are more volatile than those of smaller ships, because small ships are more versatile regarding trades and ports and therefore are not as exposed to changes in demand as larger ships.

Excess skewness is observed in all series and the negative skewness is seen for all routes and maturities. It indicates the distribution of the series has a long tail to the left relative to the right. Excess kurtosis is observed in all price series except for spot prices at the route C4. Data with excess kurtosis tend to have distinct peak near mean and drop quickly. The Jarque-Bera (1980) test clearly rejects the null hypothesis of normality at the conventional significance levels, with the exception of the route C4. The spot price series of C4 do not deviate much from the normality.

We use the Augmented Dicky-Fuller and Phillips-Perron (Dickey and Fuller, 1981; Phillips and Perron, 1988) unit root tests to test the stationarity on the log levels and log-first differences of the price series and the results show that all variables are $I(1)$.

Table 4.21: Descriptive statistics of logarithmic first differences of spot prices and one-month FFA prices

Routes	N	Mean	Std. Dev.	Skewness	Kurtosis	J-B	ADF(lags) Level	ADF(lags) 1st diff	PP(lags) Level	PP (lags) 1st diff
ILC4S	71	-0.007	0.258	-0.530	3.801	5.227 [0.07]	-2.694(1)	-6.24(0)	-2.165(3)	-6.036(11)
ILC4-1M	71	-0.008	0.221	-0.473	6.556	40.47 [0.00]	-2.50(1)	-5.933(0)	-1.982(1)	-5.675(7)
ILC7S	71	-0.007	0.279	-0.679	4.481	11.081 [0.00]	-3.065(1)	-6.511(1)	-2.362(4)	-5.88(16)
ILC7-1M	71	-0.006	0.230	-0.539	5.946	29.400 [0.00]	-2.941(1)	-6.358(1)	-2.264(2)	-5.10(12)
ILP2AS	71	-0.007	0.249	-1.591	9.569	157.60 [0.00]	-2.666(1)	-5.695(0)	-2.221(2)	-5.702(2)
ILP2A-1M	71	-0.005	0.231	-1.778	9.310	155.21 [0.00]	-2.728(1)	-5.446(0)	-2.192(2)	-5.404(3)
ILP3AS	71	-0.016	0.379	-2.216	14.678	461.55 [0.00]	-2.22(0)	-8.631(0)	-2.474(4)	-8.625(4)
ILP3A-1M	71	-0.010	0.289	-2.117	13.433	375.06 [0.00]	-2.403(1)	-6.513(0)	-2.283(3)	-6.516(2)
ILTCCS	63	-0.008	0.417	-1.049	6.175	38.431 [0.00]	-2.271(2)	-6.879(1)	-2.455(6)	-7.378(3)
ILTCC-1M	63	-0.006	0.414	-1.000	8.226	82.818 [0.00]	-2.04(2)	-6.933(1)	-2.345(5)	-4.999(12)
ILTCPS	63	-0.001	0.276	-1.098	9.499	123.08 [0.00]	-2.666(1)	-5.512(0)	-2.249(3)	-5.498(3)
ILTCP-1M	63	0.002	0.269	-1.913	11.169	213.02 [0.00]	-2.317(1)	-5.695(0)	-2.151(3)	-5.694(3)
ILTCHS	63	-0.001	0.238	-0.495	10.209	138.99 [0.00]	-2.662(1)	-5.333(0)	-2.221(3)	-5.367(3)
ILTCH-1M	63	0.000	0.243	-2.281	15.144	441.76 [0.00]	-2.248(1)	-5.754(0)	-2.095(3)	-5.790(3)

Notes:

- ILC4S, ILC7S, ILP2AS, ILP3AS mean the returns of the realized spot prices on the route C4,C7, P2A and P3A, respectively ; ILTCCS, ILTCPS and ILTCHS denote the arithmetic monthly time charter rates of all time charter routes for the Capesize, Panamax and Handymax vessels; ILC4-1M, ILC7-1M, ILP2A-1M, ILP3A-1M, ILTCC-1M, ILTCP-1M, ILTCH-1M are the returns of forward prices one month prior to maturity on routes of C4, C7, P2A, P3A, TCC, TCP and TCH, respectively;
- N is the number of observations.
- Figures in square brackets [•] indicate exact significance levels
- Skew and Kurt are the estimated centralized third and fourth moments of the data; their symptotic distributions under the null are $T\hat{\alpha}_3{}'\hat{\alpha}_3/6 \sim \chi^2(1)$ and $T(\hat{\alpha}_4-3)'(\hat{\alpha}_4-3)/24 \sim \chi^2(1)$ respectively
- J-B is the Jarque-Bera (1980) test for normality, distributed as $\chi^2(2)$
- ADF is the Augmented Dickey and Fuller (1981) test. The ADF regressions include none of intercept and trend terms. The lag length of the ADF test (in parentheses) is determined by minimizing the SBIC. PP is the Philips and Perron(1988) test; the truncation lag for the test is in parentheses. The 5% critical value for the ADF and PP tests is -2.90
- Lev and 1st diffs refer to price series in log-levels and log-first differences, respectively.

Table 4.22: Descriptive statistics of logarithmic first differences of spot prices and two-month FFA prices

Routes	N	Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	ADF(lags) Level	ADF(lags) 1st diff	PP(lags) Level	PP (lags) 1st diff
ILC4S	70	-0.011	0.258	-0.511	3.818	4.99 [0.08]	-2.696(1)	-6.24(0)	-2.188(3)	-6.036(11)
ILC4-2M	70	-0.007	0.198	-0.688	7.682	69.47 [0.00]	-2.33(1)	-5.763(0)	-1.551(0)	-5.597(6)
ILC7S	70	-0.007	0.281	-0.672	4.417	11.129[0.04]	-3.065(1)	-6.511(1)	-2.347(4)	-5.88(16)
ILC7-2M	70	-0.004	0.208	-0.617	6.862	47.95[0.00]	-2.658(1)	-5.868(1)	-2.035(1)	-5.15(9)
ILP2A	70	-0.008	0.251	-1.571	9.429	149.34[0.00]	-2.666(1)	-5.695(0)	-2.221(2)	-5.702(2)
ILP2A-2M	70	-0.003	0.220	-2.102	11.068	241.4 [0.00]	-2.717(1)	-5.289(0)	-2.023(1)	-5.062(5)
ILP3A	70	-0.019	0.381	-2.196	14.564	446.38[0.00]	-2.22(0)	-8.631(0)	-2.474(4)	-8.625(4)
ILP3A-2M	70	-0.007	0.263	-2.036	12.017	285.54[0.00]	-2.471(1)	-5.998(0)	-2.197(3)	-6.017(2)

Notes: ILC4-2M, ILC7-2M, ILP2A-2M and ILP3A-2M are the returns of forward prices two months prior to maturity on routes of C4, C7, P2A and P3A, respectively; see other notes to Table 4.21.

Table 4.23: Descriptive statistics of logarithmic first differences of spot prices and three-month FFA prices

Routes	N	Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	ADF(lags) Level	ADF(lags) 1st diff	PP(lags) Level	PP (lags) 1st diff
ILC4S	69	-0.010	0.260	-0.519	3.779	4.847 [0.09]	-2.659(1)	-6.088(0)	-2.156(3)	-5.843(12)
ILC4-3M	69	-0.008	0.183	-0.947	8.310	91.38 [0.00]	-2.255(1)	-5.555(0)	-1.724(1)	-5.369(6)
ILC7S	69	-0.006	0.282	-0.680	4.374	10.75[0.00]	-3.065(1)	-6.511(1)	-2.318(4)	-5.856(16)
ILC7-3M	69	-0.004	0.190	-0.823	7.132	56.87 [0.00]	-2.487(1)	-5.497(1)	-1.615(0)	-5.128(8)
ILP2A	69	-0.009	0.252	-1.549	9.300	141.71[0.00]	-2.662(1)	-5.662(0)	-2.217(2)	-5.676(2)
ILP2A-3M	69	-0.002	0.213	-2.188	11.280	252.2 [0.00]	-2.729(1)	-5.150(0)	-1.989(1)	-4.857(7)
ILP3A	69	-0.018	0.384	-2.190	14.393	428.31[0.00]	-2.208(0)	-8.529(0)	-2.479(4)	-8.527(4)
ILP3A-3M	69	-0.007	0.242	-1.806	10.320	191.57[0.00]	-2.517(1)	-5.577(0)	-2.076(2)	-5.561(2)

Notes: ILC4-3M, ILC7-3M, ILP2A-3M and ILP3A-3M are the returns of forward prices three months prior to maturity on routes of C4, C7, P2A and P3A, respectively; see other notes to Table 4.21.

4.4.1.3. Empirical analysis

The VECM framework proposed by Johansen will be used to test whether spot and forward prices one, two and three months prior to maturity are cointegrated during the sample period. Granger causality test is also employed to get some insight into the causal relationship between spot and forward prices. All the results below are explained in economic ways, so as to unveil the underlying dynamic relationship between the spot and FFA markets.

Cointegration between spot and FFA prices

In order to obtain a well specified VECM, the lag length of the model is estimated using a VAR model. This is in line with the fact that the lag length p of an unrestricted VAR can be re-parameterized to the lag length $p-1$ in a VECM of first differences of the dependent variable plus the level terms, see Kavussanos and Nomikos (1999). The Schwarz Bayesian Information Criterion (Schwarz, 1978), Akaike Information Criterion (Akaike, 1973) and LR test are used to determine the lag length in the models, which can be seen in Table 4.24.

Table 4.24: Johansen (1988) tests for the number of cointegrating vectors between the spot and FFA prices

	Lags	Hypothesis (maximal)		Test statistic		Hypothesis (trace)		Test statistic		95% Critical values	
		H_0	H_1	$\lambda_{\max}$	$\lambda^*_{\max}$	H_0	H_1	λ_{trace}	λ^*_{trace}	$\lambda_{\max}$	λ_{trace}
One-Month Maturity											
C4	1	$r=0$	$r=1$	40.652	39.439	$r=0$	$r=1$	45.474	44.117	15.892	20.262
		$r\le1$	$r=2$	4.822	4.678	$r\le1$	$r=2$	4.822	4.678	9.165	9.165
C7	1	$r=0$	$r=1$	31.354	30.418	$r=0$	$r=1$	35.426	34.369	15.892	20.262
		$r\le1$	$r=2$	4.072	3.950	$r\le1$	$r=2$	4.072	3.950	9.165	9.165
P2A	1	$r=0$	$r=1$	30.171	29.270	$r=0$	$r=1$	37.859	36.729	15.892	20.262
		$r\le1$	$r=2$	7.687	7.458	$r\le1$	$r=2$	7.687	7.458	9.165	9.165
P3A	1	$r=0$	$r=1$	33.627	32.623	$r=0$	$r=1$	41.261	40.029	15.892	20.262
		$r\le1$	$r=2$	7.633	7.405	$r\le1$	$r=2$	7.633	7.405	9.165	9.165
4TCC	1	$r=0$	$r=1$	34.334	33.170	$r=0$	$r=1$	40.019	38.662	15.892	20.262
		$r\le1$	$r=2$	5.686	5.493	$r\le1$	$r=2$	5.686	5.493	9.165	9.165
4TCP	1,3	$r=0$	$r=1$	30.534	28.391	$r=0$	$r=1$	35.067	32.606	15.892	20.262
		$r\le1$	$r=2$	4.533	4.215	$r\le1$	$r=2$	4.533	4.215	9.165	9.165
6TCH	3	$r=0$	$r=1$	31.96	28.599	$r=0$	$r=1$	35.546	31.804	15.892	20.262
		$r\le1$	$r=2$	3.58	3.205	$r\le1$	$r=2$	3.582	3.205	9.165	9.165
Two-Month Maturity											
C4	1	$r=0$	$r=1$	31.354	30.404	$r=0$	$r=1$	35.426	34.352	15.892	20.262
		$r\le1$	$r=2$	4.072	3.949	$r\le1$	$r=2$	4.072	3.949	9.165	9.165
C7	2	$r=0$	$r=1$	36.185	33.958	$r=0$	$r=1$	40.805	38.294	15.892	20.262
		$r\le1$	$r=2$	4.620	4.336	$r\le1$	$r=2$	4.620	4.336	9.165	9.165
P2A	2	$r=0$	$r=1$	27.785	26.075	$r=0$	$r=1$	32.709	30.696	15.892	20.262
		$r\le1$	$r=2$	4.924	4.621	$r\le1$	$r=2$	4.924	4.621	9.165	9.165
P3A	2	$r=0$	$r=1$	31.680	29.730	$r=0$	$r=1$	38.527	36.156	15.892	20.262
		$r\le1$	$r=2$	6.847	6.426	$r\le1$	$r=2$	6.847	6.426	9.165	9.165
Three-Month Maturity											
C4	2	$r=0$	$r=1$	79.048	74.108	$r=0$	$r=1$	84.688	79.395	15.892	20.262
		$r\le1$	$r=2$	5.640	5.288	$r\le1$	$r=2$	5.640	5.288	9.165	9.165
C7	2	$r=0$	$r=1$	95.508	89.539	$r=0$	$r=1$	101.81	95.455	15.892	20.262
		$r\le1$	$r=2$	6.312	5.918	$r\le1$	$r=2$	6.312	5.918	9.165	9.165
P2A	2	$r=0$	$r=1$	67.322	63.114	$r=0$	$r=1$	74.045	69.417	15.892	20.262
		$r\le1$	$r=2$	6.723	6.303	$r\le1$	$r=2$	6.723	6.303	9.165	9.165
P3A	2	$r=0$	$r=1$	71.868	67.376	$r=0$	$r=1$	77.497	72.653	15.892	20.262
		$r\le1$	$r=2$	5.629	5.277	$r\le1$	$r=2$	5.629	5.277	9.165	9.165

Notes:

- Lags is the lag length of a VAR model; the lag length is determined using the SBIC(1978), AIC(1973) and LR tests. r represents the number of cointegrating vectors
- $\lambda_{\max}(r, r+1) = -T\ln(1-\hat{\lambda}_{r+1})$ and $\lambda_{trace}(r) = -T\sum_{i=r+1}^{n}\ln(1-\hat{\lambda}_i)$ where $\hat{\lambda}_i$ are the estimated eigenvalues of the $\prod$ matrix in Eq.(1).
- $\lambda^*_{\max} = (T-kp)/T\lambda_{\max}$ and $\lambda^*_{trace} = (T-kp)/T\lambda_{trace}$ are small-sample adjusted cointegrating rank tests, where k is the number of regressors in the VECM (Reimers, 1992). Critical values are from Osterwald-Lenum(1992), Table1.

The cointegration relationship between spot and forward prices is the necessary condition for the unbiasedness hypothesis. If this necessary condition is fulfilled, the unbiasedness hypothesis is verified by testing the parameter restrictions on the cointegrating relationship. We can see from Figures 4.8-4.14 that the data do not follow a clear trend, therefore, the VEC model include neither a deterministic trend, nor an intercept, but only the intercept in the cointegrating relationship. The intercept in the cointegrating relationship is included to enable the testing of the unbiasedness hypothesis. The results from employing these models to test for cointegration are also presented in Table 4.24.

The results from the cointegration tests using Johansen's procedure indicate that spot and forward prices one-, two- and three months before maturity are cointegrated for all routes. This is a necessary condition for the unbiasedness hypothesis to hold. Because the λ_{trace} and $\lambda_{\max}$ statistic of Johansen have been shown to imply that the variables are cointegrated too often in small samples, the small sample correction proposed by Reimer (1992) is applied. Using this correction did not alter the results.

Tables 4.25-4.27 show the specifications of the VECM and summarize the results of the coefficient tests. The cointegration vector is defined as $\beta' = (1, \beta_1, \beta_2)$. To test for the unbiasedness, we have to test whether $\beta_1 = 0$ and $\beta_2 = 1$. We can see that the null hypotheses that the restrictions are binding cannot be rejected neither for the single- nor for the joint hypotheses for all routes and for all maturities. The acceptance of the null hypothesis shows that there exists no systematic risk premium and the agents have rational expectations in almost all the investigated routes.

The results for the one-month price series can be found in Table 4.25. The Johansen methodology test indicates that the unbiasedness hypothesis can hold for almost all the routes with the exception of 6TCH for Handymax vessels, where the hypothesis can be rejected at the 10% significance level. The results for the two-month price series can be shown in Table 4.26. The Johansen methodology suggests that the unbiasedness hypothesis holds for all the investigated routes. Table 4.27 contains the results for the three months price series, and the results still support the unbaisedness hypothesis for all the investigated routes.

Table 4.25: Model specifications and tests of the unbiasedness for the one-month FFA and spot prices

Panel A: Model Specification-One-Month Maturity

$$\begin{pmatrix} \Delta S_t \\ \Delta F_{t-1,t} \end{pmatrix} = \sum_{i=1}^{p} \Gamma_i \begin{pmatrix} \Delta S_{t-i} \\ \Delta F_{t-2,t-i} \end{pmatrix} + \begin{pmatrix} \alpha_1 \\ \alpha_2 \end{pmatrix} (1 \quad \beta_1 \quad \beta_2) \begin{pmatrix} S_{t-1} \\ 1 \\ F_{t-2,t-1} \end{pmatrix} + \begin{pmatrix} \varepsilon_{st} \\ \varepsilon_{ft} \end{pmatrix}, \begin{pmatrix} \varepsilon_{st} \\ \varepsilon_{ft} \end{pmatrix} \sim iid(0, \Sigma)$$

Routes	Lags	Coefficients Estimates		Hypothesis Tests on β'					
		α_1	α_2	$\beta' = (1\ \beta_1\ \beta_2)$			$H_0: \beta_1 = 0$	$H_0: \beta_2 = -1$	$H_1: \beta_1 = 0\ and\ \beta_2 = -1$
C4	1	-0.326 (-0.851)	0.654** (5.244)	1	-0.061	-0.976	0.366 [0.545]	0.888 [0.346]	1.373 [0.503]
C7	1	-0.193 (-0.436)	0.612** (5.539)	1	-0.046	-0.982	0.235 [0.628]	0.520 [0.471]	1.387 [0.500]
P2A	1	0.246 (0.725)	0.599** (4.666)	1	-0.007	-0.999	0.082 [0.775]	0.007 [0.931]	0.093 [0.955]
P3A	1	0.331 (0.913)	0.632** (5.307)	1	0.595	-1.055	2.434 [0.119]	1.614 [0.203]	3.952 [0.139]
4TCC	1	0.856 (1.343)	1.263** (3.827)	1	-0.191	-0.982	1.558 [0.212]	1.394 [0.238]	2.877 [0.237]
4TCP	1,3	0.686 (1.568)	1.143** (3.967)	1	0.132	-1.012	0.496 [0.481]	0.461 [0.497]	0.730 [0.694]
6TCH	3	1.759** (2.77)	1.969** (4.58)	1	-0.312	-0.970	2.90 [0.089]	2.769 [0.096]	5.66 [0.059]

Notes:

- α_1 and α_2 are the coefficient estimates of the error correction model implied by the normalised cointegrating parameters, *t*-statistics for the null hypothesis ($\alpha_1 = 0$) are in parentheses (.).

- Estimates of the coefficients in the cointegrating vector are normalised with respect to the coefficient of the spot rate S_t.
- The statistic for the unbiasedness hypothesis tests on the coefficients of the cointegrating vector is $-T[\ln(1-\hat{\lambda}_1^*)-\ln(1-\hat{\lambda}_1)]$ where $\hat{\lambda}_1^*$ and $\hat{\lambda}_1$ denote the largest eigenvalues of the restricted and the unrestricted models, respectively. The statistic is distributed as χ^2 with degrees of freedom equal to the number of restrictions placed on the cointegrating vector.
- Exact significance levels are in square brackets [.].

Table 4.26: Model specifications and tests of the unbiasedness for the two-month FFA and spot prices

Panel A: Model Specification-Two-Month Maturity

$$\begin{pmatrix}\Delta S_t\\ \Delta F_{t-1,t}\end{pmatrix} = \sum_{i=1}^{p}\Gamma_i \begin{pmatrix}\Delta S_{t-i}\\ \Delta F_{t-2,t-i}\end{pmatrix} + \begin{pmatrix}\alpha_1\\ \alpha_2\end{pmatrix}(1\quad \beta_1\quad \beta_2)\begin{pmatrix}S_{t-1}\\ 1\\ F_{t-2,t-1}\end{pmatrix} + \begin{pmatrix}\varepsilon_{st}\\ \varepsilon_{ft}\end{pmatrix}, \begin{pmatrix}\varepsilon_{st}\\ \varepsilon_{ft}\end{pmatrix} \sim iid(0,\Sigma)$$

Routes	Lags	Coefficients Estimates		Hypothesis Tests on β'					
		α_1	α_2	$\beta' = (1\ \beta_1\ \beta_2)$			$H_0: \beta_1 = 0$	$H_0: \beta_2 = -1$	$H_1: \beta_1 = 0$ and $\beta_2 = -1$
C4	1	-0.185 (-1.227)	0.738** (15.329)	1	-0.056	-0.979	0.299 [0.585]	0.326 [0.568]	0.339 [0.844]
C7	2	0.198 (0.501)	0.599** (6.535)	1	-0.095	-0.970	1.224 [0.542]	1.119 [0.29]	1.305 [0.521]
P2A	2	0.327 (1.281)	0.443** (4.717)	1	-0.148	-0.987	0.343 [0.558]	0.003 [0.955]	1.487 [0.476]
P3A	2	0.167 (0.617)	0.459** (5.579)	1	0.119	-1.008	0.250 [0.617]	0.196 [0.658]	1.703 [0.427]

See notes to Table 4.25.

Table 4.27: Model specifications and tests of the unbiasedness for the three-month FFA and spot prices

Panel A: Model Specification-Three-Month Maturity

$$\begin{pmatrix}\Delta S_t\\ \Delta F_{t-1,t}\end{pmatrix} = \sum_{i=1}^{p}\Gamma_i \begin{pmatrix}\Delta S_{t-i}\\ \Delta F_{t-2,t-i}\end{pmatrix} + \begin{pmatrix}\alpha_1\\ \alpha_2\end{pmatrix}(1\quad \beta_1\quad \beta_2)\begin{pmatrix}S_{t-1}\\ 1\\ F_{t-2,t-1}\end{pmatrix} + \begin{pmatrix}\varepsilon_{st}\\ \varepsilon_{ft}\end{pmatrix}, \begin{pmatrix}\varepsilon_{st}\\ \varepsilon_{ft}\end{pmatrix} \sim iid(0,\Sigma)$$

Routes	Lags	Coefficients Estimates		Hypothesis Tests on β'					
		α_1	α_2	$\beta' = (1\ \beta_1\ \beta_2)$			$H_0: \beta_1 = 0$	$H_0: \beta_2 = -1$	$H_1: \beta_1 = 0$ and $\beta_2 = -1$
C4	2	-0.113 (-0.72)	0.623** (11.75)	1	-0.102	-0.969	0.922 [0.337]	0.687 [0.407]	1.665 [0.435]
C7	3	-0.321 (-0.94)	0.408** (4.656)	1	-0.237	-0.926	1.971 [0.16]	1.688 [0.19]	2.693 [0.26]
P2A	2	0.059 (0.04)	0.615** (10.234)	1	-0.152	-0.989	0.108 [0.742]	0.06 [0.80]	4.134 [0.127]
P3A	2	-0.132 (-0.52)	0.434** (5.367)	1	-0.548	-0.944	0.705 [0.703]	0.663 [0.415]	0.955 [0.620]

See notes to Table 4.25.

Table 4.28: The residual diagnostics for the VEC models in all routes

Panel B: Residual Diagnostics

Routes	Residuals	One-Month Maturity			Two-Month Maturity			Three-Month Maturity		
		$Q(12)$	$Q^2(12)$	J-B	$Q(12)$	$Q^2(12)$	J-B	$Q(12)$	$Q^2(12)$	J-B
C4	$\varepsilon_{s,t}$	11.055 [0.524]	27.087 [0.008]	1.929 [0.38]	10.860 [0.541]	24.165 [0.019]	2.58 [0.273]	13.175 [0.356]	23.546 [0.023]	9.32 [0.009]
	$\varepsilon_{f,t}$	13.196 [0.355]	16.462 [0.171]	9.35 [0.009]	20.219 [0.063]	15.361 [0.222]	1.256 [0.533]	18.095 [0.113]	13.499 [0.410]	1.347 [0.509]
C7	$\varepsilon_{s,t}$	8.795 [0.720]	13.344 [0.345]	8.126 [0.017]	9.22 [0.684]	16.150 [0.184]	11.749 [0.003]	9.974 [0.618]	13.438 [0.338]	23.526 [0.00]
	$\varepsilon_{f,t}$	21.267 [0.047]	9.656 [0.646]	30.853 [0.00]	10.314 [0.588]	12.708 [0.391]	8.497 [0.014]	22.229 [0.120]	19.711 [0.011]	0.984 [0.611]
P2A	$\varepsilon_{s,t}$	10.750 [0.55]	9.331 [0.700]	30.667 [0.00]	12.956 [0.372]	4.638 [0.978]	81.214 [0.00]	10.941 [0.534]	5.625 [0.948]	85.261 [0.00]
	$\varepsilon_{f,t}$	8.989 [0.704]	50.253 [0.00]	3.514 [0.17]	8.691 [0.729]	10.354 [0.585]	2.014 [0.365]	16.625 [0.164]	17.719 [0.125]	0.682 [0.711]
P3A	$\varepsilon_{s,t}$	13.529 [0.332]	4.262 [0.978]	369.39 [0.00]	8.045 [0.782]	0.331 [1.0]	416.63 [0.00]	8.569 [0.739]	0.704 [1.00]	372.06 [0.00]
	$\varepsilon_{f,t}$	9.496 [0.660]	17.973 [0.117]	61.62 [0.00]	11.616 [0.477]	21.538 [0.043]	2.117 [0.347]	14.183 [0.289]	14.156 [0.291]	4.275 [0.118]
4TCC	$\varepsilon_{s,t}$	9.964 [0.619]	14.443 [0.071]	2.341 [0.310]	-	-	-	-	-	-
	$\varepsilon_{f,t}$	12.775 [0.386]	8.689 [0.729]	0.422 [0.810]	-	-	-	-	-	-
4TCP	$\varepsilon_{s,t}$	12.23 [0.428]	7.454 [0.826]	47.512 [0.00]	-	-	-	-	-	-
	$\varepsilon_{f,t}$	11.085 [0.522]	44.018 [0.00]	1.678 [0.432]	-	-	-	-	-	-
6TCH	$\varepsilon_{s,t}$	8.222 [0.768]	14.868 [0.249]	1.428 [0.489]	-	-	-	-	-	-
	$\varepsilon_{f,t}$	11.151 [0.516]	11.728 [0.518]	2.487 [0.288]	-	-	-	-	-	-

Notes:

- $\varepsilon_{s,t}$ and $\varepsilon_{f,t}$ are the estimated residuals from the spot and the FFA equation in the VECM, respectively.
- ♦ $Q(12)$ is the Ljung-Box (1978) Q statistic of the sample autocorrelation function on the first 12 lags and is distributed as $\chi^2(12)$. The critical values are 26.22 and 21.03 for the 1% and 5% levels, respectively
- J-B is the Jarque-Bera (1980) test for normality and is distributed as $\chi^2(2)$. Exact significance levels are in square brackets [.].

We may conclude based on these results that the FFA prices one, two and three months prior to maturity seem to be the unbiased expectations forecasts of the realized spot prices at the conventional significance levels on all the investigated routes of C4, C7, P2A and P3A. The forward prices of 4TC average could be the unbiased expectations of the realized monthly spot prices for Capesize and Panamax vessels, respectively. While those for Handymax vessels are observed to be the biased estimators of the realized monthly spot prices at the 10% significance level.

In order to investigate the short-run properties of spot and FFA prices, we examine the estimated error correction coefficients of spot prices α_1 and of FFA prices α_2, which show the speed of the convergence to the equilibrium state, and the larger the coefficient the faster the equilibrium is reached. The estimates are also reported in Tables 4.25-4.27. We can see that for all contracts the error correction coefficient of forward rates α_2 is highly significant and positive whereas that of spot rates α_1 is statistically insignificant, with the exception of the one-month forward contract of 6THC. A positive α_2 implies that a positive error at the period $t-1$ will be followed by a relative increase in the price of the forward contract in the next period.

Hence it is only the forward contract that corrects previous deviations from the long run equilibrium. This means that past errors affect the current forecasts of the underlying realized spot rates, but not the spot prices themselves. If new information arises in the market it is the forward rate that reacts to correct the forecast error whereas the spot price remains unaffected. This is the further evidence for the unbiasedness of FFA's. New information is immediately incorporated in the forward prices which is an important feature of an efficient market. The same results are also found in Kavussanos and Nomikos (1999) and Kavussanos, Visvikis and Mechanof (2004). It is argued that higher transaction costs in the spot market are the driving force behind these results, because the commission in the physical business is much higher than in the forward market (2.5-5% on average in the physical market vs. 0.25-0.50% in the forward market), and it is much easier to trade forward contracts than physical vessels.

Turing into the FFA price series of time charter average of the Handymax, we can see that both α_1 and α_2 are positive and significant at the 5% significance level. This is consistent with the results regarding the presence of a bias in this contract. The positive signs of both error correction coefficients indicate that a positive forecast error at period $t-1$ will force both forward and spot prices to increase, hence any disequilibrium at period $t-1$ is also carried forward to period t, implying that past forecast errors affect not only the FFA prices, but also the realized spot prices.

Further explanation of the results

FFA prices are empirically found to be the unbiased estimators of the underlying spot prices on almost all the investigated routes for different maturities. This implies that the market agents hold rational expectations and there is no risk premium on these routes. Specifically, this means that all available information is reflected in the price of a forward contract and this price will only be affected by new information. Rational expectations do not mean that market participants can receive all the new market information, because new information is not available simultaneously in the freight forward market. The fact that new information not available simultaneously in the freight forward market will induce time-related trading opportunities for the well informed market participants and it will therefore not prevent the forward prices from being the unbiased estimators of the underlying spot prices.

Freight forward prices may have forecasting abilities regardless of whether the unbiased hypothesis holds. The FFA price n months from maturity provides a forecast of the underlying settlement price on the maturity day. The forecasting performance of FFA prices for 4TCC, 4TCP and 6TCH one month prior to maturity and the forecasting capabilities of daily FFA and daily spot prices at routes of C4, C7, P2A and P3A will be investigated in the section 4.5.

4.4.2. The lead-lag relationship between forward prices and spot prices

The primary benefits that forward markets provide to the economic agents are price discovery and risk management through hedging. Price discovery is the process of revealing information about future spot prices through the forward/forward markets. Risk management refers to hedgers using forward contracts to control their spot price risk. In this part the price discovery properties of freight forward prices are further explored by investigating the lead-lag relationship between daily forward prices and daily spot rates. The lead-lag relationship between forward prices and spot rates refers to how well the two markets are linked and how fast one of the markets reflects new information relative to the other. Assuming that new information is available to both markets at the same time, the markets should theoretically react simultaneously. This might however not be the case in the real world as market factors such as transaction costs, short-sale restrictions or flexibility might favor trading in one of the markets. In line with this, one market might lead the other, and thus work as a price discovery vehicle. The previous research regarding the lead-lag relationship between future/forward prices and spot ones can be found in Kavussanos and Nomikos (2003), Kavussanos and Visvikis (2004), Kavussanos, Visvikis and Menachof (2004) among others, as described in Chapter 3.

4.4.2.1. Methodology

The causal relationship between spot and forward prices in the FFA market is investigated using the Vector Error Correction model (VECM) (Johansen, 1988). If spot and forward prices are cointegrated, then causality must exist in at least one direction (Granger, 1986). To test causality formally, the following expanded VECM may be estimated using OLS in each equation.

$$\begin{aligned} \Delta S_t &= \sum_{i=1}^{p-1} a_{s,i}\Delta S_{t-i} + \sum_{i=1}^{p-1} b_{s,i}\Delta F_{t-i} + \alpha_s Z_{t-1} + \varepsilon_{s,t} \\ \Delta F_t &= \sum_{i=1}^{p-1} a_{f,i}\Delta F_{t-i} + \sum_{i=1}^{p-1} b_{f,i}\Delta S_{t-i} + \alpha_f Z_{t-1} + \varepsilon_{f,t} \end{aligned} \tag{4.28}$$

Where $a_{s,i}$, $b_{s,i}$, $a_{f,i}$, $b_{f,i}$ are the short-run coefficients and Z_t is the error correction term from the system of Equations (4.28). A time series F_t is said to Granger cause another time series S_t, if the present values of S_t can be predicted more accurately by using past values of F_t than by not doing so, considering also other relevant information including past values of S_t (Granger, 1969). In terms of the VECM of Equations (4.28), F_t Granger causes S_t if some of the $b_{s,i}$ coefficients, are not zero and/or a_s the error correction coefficient in the equation for spot prices, is significant at conventional levels. Similarly, S_t Granger causes F_t if some of the $b_{f,i}$ coefficients are not zero and/or a_f is significant at conventional levels. These hypotheses can be tested using t-tests for the significance of the error correction coefficients and F-tests on the joint significance of the lagged estimated coefficients. If both S_t and F_t Granger cause each other then there is a two-way feedback relationship between the two markets. Therefore, the error correction coefficients, a_s and a_f serve two purposes: to identify the direction of causality between spot and forward prices and to measure the speed with which deviations from the long-run relationship are corrected by changes in the spot and forward prices.

4.4.2.2. Description of data properties

The data used to investigate the lead-lag relationship consist of daily data of spot and forward prices during the period of Jan 4th 2005 to December 24th 2010 for the most-liquid routes of C4 and C7 for Capesize vessels as well as P2A and P3A for Panamax vessels. The descriptions of each route can be found in Table 4.20. Forward prices are collected together with spot prices for each route. The forward price series contain forward prices of the first nearby and the second nearby contracts, because they are highly liquid and are the most active contracts. As maturity approaches, the liquidity of a forward contract falls sharply and contracts of one month and two months prior to maturity have been rolled over at the last day of the expiry month and the month before expiry, respectively.

Combining information from forward contracts with different times to maturity may create structural breaks in the series at the date of the forward contract rollover since forward returns for that day are calculated between the price of an expiring contract and the price of the next nearest contract. Such structural breaks in the series may possibly lead to biased results.

In order to examine whether there exist the structural breaks of forward prices closest to maturity, ARIMA regressions are employed, which included a dummy variable taking the value one each time the forward contracts were rolled and zero others. Results however show that all the forward price series of the first nearby contract contain structural breaks at the significance levels. Since structural breaks may lead to biased results, we construct a ‘perpetual’ series of forward prices for all routes. The series were based on the weighted average of prices of one month and two-months forward contracts, weighted according to their respective number of days from maturity. This procedure generates a series of forward prices with a constant maturity on each route and avoids the problem of price-jumps caused by the expiration of a particular forward contract, see Schwager (1996).

The spot and the adjusted forward price series with corresponding observations therefore are obtained, yielding data sets with 1499 observations on routes of C4 and C7 for Capesize vessels, as well as P2A and P3A for Panamax vessels. The movement of all spot and forward prices are displayed in Figures 4.15-16.

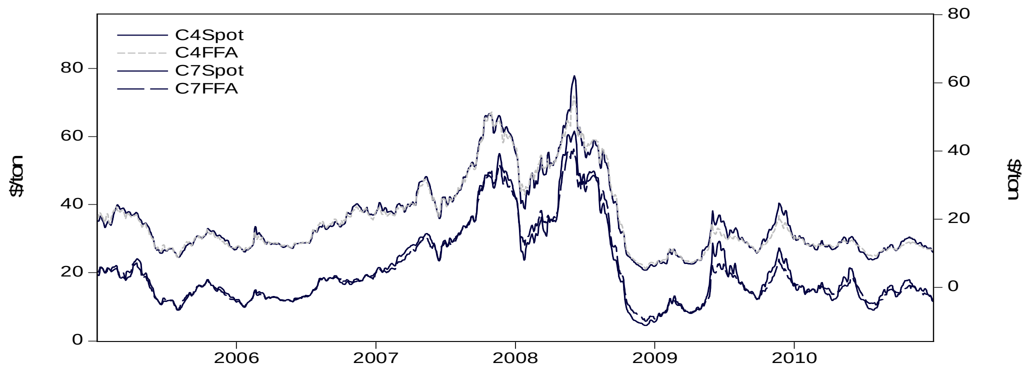

Figure 4.15: Spot and adjusted FFA prices on routes of C4 and C7 during 4th Jan 2005 to 24th Dec 2010

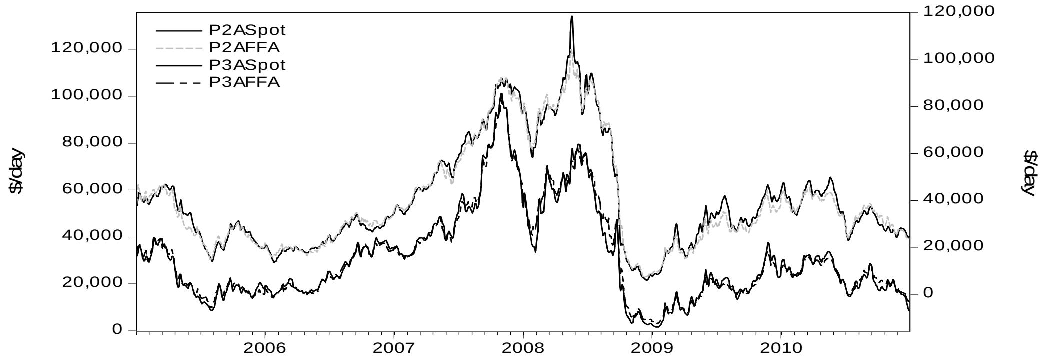

Figure 4.16: Spot and adjusted FFA prices on routes of P2A and P3A during 4th Jan 2005 to 24th Dec 2010

The whole sample period can be characterized by distinct three phases, namely the booming phase, fundamentally driven by the relatively high demand, the collapsing phase and the trough phase, fundamentally determined by the sluggish demand and the surplus of tonnage. As we all know, the market has stepped into recession and started to drop sharply since September 2008. Prices have changed dramatically and trends have been distinctly different since the outbreak of the financial crisis, which may create structural breaks in the series during the whole period.

Furthermore, during the market collapsing period, fixtures were very limited and spot rates dropped even below the operational cost level. The market at that moment was filled with panic and pessimistic sentiment and many ship brokers had no ideas about the market movement. They arbitrarily estimated shipping prices in case of no fixtures and this may cause prices extremely volatile. As a result, the collapsing phase should also be separated from the whole period.

Finally, if a VEC model is estimated between daily spot and forward prices over the whole sample period of 4th Jan, 2005 to 24th Dec, 2010, the autocorrelation of residuals resulting from the model can never be removed.

Consequently, the whole sample period is split into three sub-periods: the first sub-period runs from 4th Jan, 2005 to 29th Aug,2008; the second covers 1st Sept, 2008 to 30th Jan, 2009 and the third is from 2nd Feb, 2009 to 24th Dec, 2010. All series are also transformed in natural logarithms. Descriptive statistics of the first differences of the series used in this analysis are presented in Table 4.29.

Table 4.29: Descriptive statistics of the logarithmic first differences of spot prices and one-month FFA prices

Routes	N	Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	ADF(lags) Level	ADF(lags) 1st diff	PP(lags) Level	PP (lags) 1st diff
Sub-period One										
ILC4S	915	0.00064	0.0233	0.161	9.541	1635 [0.00]	-1.19(2)	-15.25(1)	-1.14(11)	-12.09(10)
ILC4F	915	0.00063	0.0231	0.087	5.385	218 [0.00]	-1.03(1)	-16.61(0)	-0.75(15)	-17.05(18)
ILC7S	915	0.00064	0.0189	-0.403	8.769	1293[0.00]	-1.17(2)	-12.63(1)	-1.09(11)	-10.92(16)
ILC7F	915	0.00072	0.0180	-0.129	5.801	301[0.00]	-0.71(2)	-16.37(1)	-0.69(13)	-16.36(6)
ILP2AS	915	0.00067	0.018	0.046	4.503	86[0.00]	-0.76(2)	-13.63(1)	-0.72(13)	-8.75(15)
ILP2AF	915	0.00070	0.021	0.187	5.090	171 [0.00]	-0.68(2)	-17.70(1)	-0.58(10)	-17.56(8)
ILP3AS	915	0.00002	0.026	0.403	5.861	336[0.00]	-1.48(2)	-13.79(1)	-1.35(12)	-8.12(13)
ILP3AF	915	0.00036	0.025	-0.017	5.831	305[0.00]	-1.21(1)	-15.24(0)	-1.01(8)	-15.47(14)
Sub-period Two										
ILC4S	104	-0.0156	0.036	-0.841	5.567	40.8 [0.00]	-2.51(2)	-4.45(0)	-2.87(6)	-4.47(0)
ILC4F	104	-0.0142	0.031	-0.207	2.822	0.88 [0.64]	-2.82(1)	-3.84(0)	-3.17(7)	-3.92(9)
ILC7S	104	-0.0137	0.038	0.277	4.822	15.7[0.00]	-2.25(1)	-3.10(0)	-2.62(5)	-3.41(3)
ILC7F	104	-0.0143	0.033	-0.160	2.719	0.78[0.67]	-2.86(1)	-4.55(0)	-3.00(7)	-4.63(5)
ILP2AS	104	-0.0165	0.049	-0.759	5.120	29.5[0.00]	-2.42(2)	-3.67(1)	-2.50(6)	-3.17(1)
ILP2AF	104	-0.0169	0.042	-0.319	2.593	2.48 [0.29]	-2.51(1)	-3.76(0)	-2.57(7)	-3.74(4)
ILP3AS	104	-0.0201	0.090	0.547	4.652	17.0[0.00]	-1.85(1)	-3.78(1)	-1.46(7)	-3.35(1)
ILP3AF	104	-0.0202	0.068	-0.043	2.588	0.77[0.68]	-1.91(1)	-5.04(0)	-1.76(7)	-5.18(1)
Sub-period Three										
ILC4S	479	0.0008	0.031	1.693	12.841	2161 [0.00]	-2.64(2)	-11.27(0)	-2.56(16)	-10.19(14)
ILC4F	479	0.0005	0.024	3.105	33.596	19453 0.00]	-2.33(1)	-13.26(0)	-2.28(9)	-13.28(3)
ILC7S	479	0.0007	0.032	0.835	5.298	160[0.00]	-2.75(4)	-8.09(3)	-2.69(11)	-9.14(22)
ILC7F	479	0.0007	0.023	3.367	34.193	20324[0.00]	-2.55(2)	-9.21(1)	-2.53(12)	-12.54(5)
ILP2AS	479	0.0014	0.026	-0.103	5.671	143[0.00]	-3.19(2)	-	-3.32(10)	-
ILP2AF	479	0.0013	0.028	0.762	5.581	179 [0.00]	-3.31(1)	-	-3.23(7)	-
ILP3AS	479	0.0015	0.044	1.046	7.997	586[0.00]	-3.57(2)	-	-3.41(9)	-
ILP3AF	479	0.0015	0.036	1.245	9.810	1049[0.00]	-3.23(1)	-	-3.18(8)	-

Notes:

- All series are measured in logarithmic first differences. N is the number of observations.
- Figures in square brackets [•] indicate exact significance levels
- Skew and Kurt are the estimated centralized third and fourth moments of the data; their symptotic distributions under the null are $T\hat{\alpha}_3{}'\hat{\alpha}_3/6 \sim \chi^2(1)$ and $T(\hat{\alpha}_4-3)'(\hat{\alpha}_4-3)/24 \sim \chi^2(1)$ respectively
- J-B is the Jarque-Bera (1980) test for normality, distributed as $\chi^2(2)$
- ADF is the Augmented Dickey and Fuller (1981) test. The ADF regressions include none of intercept and trend terms. The lag length of the ADF test (in parentheses) is determined by minimizing the SBIC. PP is the Philips and Perron(1988) test; the truncation lag for the test is in parentheses. The 5% critical values for the ADF and PP tests during the first, the second and the third sub-period are -2.864, -2.889 and -2.867, respectively.
- Lev and 1st diffs refer to price series in log-levels and log-first differences, respectively.

As expected, the mean is positive and close to zero for all the series during the first and the third sub-periods. Whereas during the second sub-period, it is significantly negative, implying that prices fell over the period. For the standard deviation, the collapsing period exhibits the highest standard deviation for both spot and forward prices, indicating it's the most volatile period among all. Furthermore, comparing different routes, we can find that the standard deviation on the route P3A is the highest in each sub-period. The reason why spot and forward prices on route P3A seem to be more unstable than others might be that the transpacific trading area is the most active one among all, driven by the large demand from Asia during the sample period.

The skewness is positive for almost all the series during the third sub-period except for the P2A spot series. Most of the series are thereby right skewed, meaning that the distributions of all the time series except for the spot price series on the route P2A have a relatively long tail to the right. For the other two periods, the sign of the skewness is mixed. The high kurtosis in almost all the price series shows that the distributions are leptokurtic, meaning that they have a distinct peak near the mean, decline rapidly and have heavy tails. This can be attributed to many observations around zero and some outliers. The high Jarque-Bera statistics can be regarded as a consequence of all factors influencing the skewness and kurtosis. This test indicates that most of the series depart from the normal distribution with the exception of the forward price series during the second sub-period.

The stationarity of the series is investigated by the ADF and PP tests. Results show that almost all the spot and forward prices are found to be non-stationary in levels, but stationary in first differences. Exceptions are spot and forward prices on P2A and P3A during the third sub-period, when they are observed to be stationary in levels at the 5% significance level.

4.4.2.3. The lead-lag relationship between spot and forward prices

Johansen's cointegration framework is now employed to test for cointegration. The models used include a constant in the cointegrating relationship, but not outside and no trend. The Schwarz Bayesian Information Criterion (Schwarz, 1978), Akaike Information Criterion (Akaike, 1973) and LR test are used to determine the lag length in the VEC models. Using these lag-lengths the Johansen (1988) procedure is employed to test the cointegrating relationship between spot and forward prices for all the routes except for P2A and P3A during the trough phase, because they are stationary at levels. Results of cointegration tests are presented in Table 4.30.

For the routes where cointegration relationship is found, the error correction model is used to make the analysis of the lead-lag relationship between variables. Results of the estimates of VEC models are presented in Tables 4.31-4.32. The residual diagnostics in the same tables show that no sign of autocorrelation is detected for all cases, indicating models are correctly specified. Since heteroskedasticity can be seen for almost cases, all the t-statistics are adjusted by the White (1980) heteroskedasticity correction.

During the first sub period, results of cointegration tests reveal that there is one cointegration relationship between the spot and perpetual forward prices for all routes. A VECM will therefore be used to investigate the lead-lag relationship for these routes. Results from the estimates of VEC models indicate that coefficients of the error correction term (ECT) of the spot equation are all significantly negative, but the coefficient of the ECT of the forward equation is not significant for all routes including C4, C7, P2A and P3A. This implies that only the spot prices react to correct a shock to the system in order to reach the long-term equilibrium, while the forward prices remain unresponsive. The ECT coefficients of the spot equation are larger in magnitude than those of the forward one.

More rigorous investigation of interactions between variables can be obtained by performing Granger causality tests, which are presented in the same tables. The results reveal that in all routes, there is a two-way feedback causal relationship between the forward market and the spot market at the 5% significance level. Additionally, coefficients of the forward lags in the spot equations are broadly larger in magnitude than coefficients of the spot lags in the forward equations on all routes. It means that the impact of lagged forward returns on the spot market is far stronger than the impact of spot returns on the forward market.

Table 4.30: Johansen (1988) tests for the number of cointegrating vectors between the spot and FFA prices

	Lags	Hypothesis (maximal)		Test statistic	Hypothesis (trace)		Test Statistic	95% Critical values		Cointegrating vector
		H_0	H_1	$\lambda_{\max}$	H_0	H_1	λ_{trace}	$\lambda_{\max}$	λ_{trace}	$\beta' = (1, \beta_1, \beta_2)$
Period One										
C4	2	$r=0$	$r=1$	37.94	$r=0$	$r=1$	38.89	15.89	20.26	(1, 0.017,-1.005)
		$r\le 1$	$r=2$	0.95	$r\le 1$	$r=2$	0.95	9.16	9.16	
C7	2	$r=0$	$r=1$	23.53	$r=0$	$r=1$	24.41	15.89	20.26	(1,-0.01, -0.998)
		$r\le 1$	$r=2$	0.88	$r\le 1$	$r=2$	0.88	9.16	9.16	
P2A	2	$r=0$	$r=1$	24.80	$r=0$	$r=1$	25.44	15.89	20.26	(1, 0.168,-1.016)
		$r\le 1$	$r=2$	0.64	$r\le 1$	$r=2$	0.64	9.16	9.16	
P3A	1	$r=0$	$r=1$	18.34	$r=0$	$r=1$	19.66	15.89	20.26	(1,-0.185,-0.98)
		$r\le 1$	$r=2$	1.32	$r\le 1$	$r=2$	1.32	9.16	9.16	
Period Two										
C4	1	$r=0$	$r=1$	12.69	$r=0$	$r=1$	21.82	15.89	20.26	-
		$r\le 1$	$r=2$	9.13	$r\le 1$	$r=2$	9.13	9.16	9.16	
C7	1	$r=0$	$r=1$	15.32	$r=0$	$r=1$	18.97	15.89	20.26	-
		$r\le 1$	$r=2$	3.65	$r\le 1$	$r=2$	3.65	9.16	9.16	
P2A	1	$r=0$	$r=1$	21.40	$r=0$	$r=1$	28.74	15.89	20.26	(1, 0.503,-1.044)
		$r\le 1$	$r=2$	7.33	$r\le 1$	$r=2$	7.33	9.16	9.16	
P3A	1	$r=0$	$r=1$	19.12	$r=0$	$r=1$	24.06	15.89	20.26	(1, 2.067,-1.195)
		$r\le 1$	$r=2$	4.94	$r\le 1$	$r=2$	4.94	9.16	9.16	
Period Three										
C4	2	$r=0$	$r=1$	26.67	$r=0$	$r=1$	35.01	15.89	20.26	(1,0.675,-1.282)
		$r\le 1$	$r=2$	8.43	$r\le 1$	$r=2$	8.43	9.16	9.16	
C7	7	$r=0$	$r=1$	31.69	$r=0$	$r=1$	40.75	15.89	20.26	(1,0.382,-1.154)
		$r\le 1$	$r=2$	9.05	$r\le 1$	$r=2$	9.05	9.16	9.16	
P2A	2	$r=0$	$r=1$	-	$r=0$	$r=1$	-	15.89	20.26	-
		$r\le 1$	$r=2$	-	$r\le 1$	$r=2$	-	9.16	9.16	
P3A	2	$r=0$	$r=1$	-	$r=0$	$r=1$	-	15.89	20.26	-
		$r\le 1$	$r=2$	-	$r\le 1$	$r=2$	-	9.16	9.16	

See notes to Table 4.24.

Table 4.31: The estimates of VEC models for Capesize vessels during the sample period of 2005.1.4-2010.12.24

	Period One: 2005.1.4-2008.8.29				*Period Three:2009.2.2-2010.12.24*			
Routes	C4		C7		C4		C7	
Variables	Spot	FFA	Spot	FFA	Spot	FFA	Spot	FFA
$\alpha_{s,f}$	-0.059** (-3.176)	-0.013 (-0.624)	-0.032** (-2.332)	-0.003 (-0.192)	-0.031** (-1.799)	0.050** (3.085)	-0.042** (-2.987)	0.033** (2.516)
ΔS_{t-1}	0.420** (5.658)	0.026 (0.321)	0.583** (7.055)	0.207** (2.507)	0.449* (8.411)	0.114** (2.247)	0.608** (13.05)	-
ΔS_{t-2}	-0.081** (-2.949)	-0.107** (-2.087)	-0.089* (-1.890)	-0.091* (-1.659)	-0.189** (-3.932)	-0.087** (-1.909)	-	0.126** (2.580)
ΔS_{t-3}							-0.151** (-2.781)	-0.072 (-1.309)
ΔS_{t-4}							0.134** (2.731)	0.087* (1.913)
ΔS_{t-7}							0.152** (4.342)	0.060 (1.532)
ΔF_{t-1}	0.397** (11.331)	0.511** (9.877)	0.303** (6.530)	0.417* (8.273)	0.462** (8.021)	0.393** (7.189)	0.297** (5.191)	0.435** (9.656)
ΔF_{t-2}	0.027 (0.564)	-0.029 (-0.547)	0.009 (0.163)	0.014 (0.229)	0.138** (2.231)	0.052 (0.885)	0.112** (1.965)	0.083 (1.468)
ΔF_{t-3}							-0.065 (1.061)	-0.105* (-1.896)
ΔF_{t-5}							-0.177** (-3.211)	-0.100* (-1.937)
ΔF_{t-6}								-0.089* (-1.769)
ΔF_{t-7}								0.072 (1.343)
Granger causality test	Spot→FFA	FFA→Spot	Spot→FFA	FFA→Spot	Spot→FFA	FFA→Spot	Spot→FFA	FFA→Spot
	6.124 [0.047]	158.95 [0.00]	14.26 [0.00]	77.91 [0.00]	12.533 [0.03]	63.49 [0.00]	9.12 [0.244]	45.28 [0.00]
J-B test	1847.33 [0.00]	287.89 [0.00]	2217.58 [0.00]	635.52 [0.00]	3348.91 [0.00]	26891 [0.00]	187 [0.00]	11918 [0.00]
$Q(36)$	38.624 [0.352]	34.581 [0.549]	32.692 [0.627]	27.028 [0.86]	41.203 [0.247]	33.581 [0.596]	25.06 [0.91]	42.08 [0.224]
$Q^2(36)$	137.72 [0.00]	65.375 [0.00]	151.82 [0.00]	89.83 [0.00]	38.570 [0.354]	11.091 [0.99]	106.55 [0.00]	14.02 [0.99]
$\bar{R}^2$	0.597	0.256	0.613	0.308	0.504	0.241	0.576	0.339

Notes:

- All series are measured in logarithmic first differences. Δ means the first difference. S_t denotes the spot rates at time t, F_t refers to the forward price with the perpetual maturity
- * and ** denote significance at the 5% and 10% levels, respectively.
- Figures in parentheses (.) and in squared brackets [.] indicate *t*-statistics and exact significance levels, respectively.
- *t*-statistic and Wald tests are adjusted using the White (1980) heteroskedasticity consistent variance-covariance matrix, in the cases of heteroskedasticity in the residuals.
- J-B is the Jarque-Bera (1980) test for normality, distributed as $\chi^2(2)$.
- $Q(36)$ and $Q^2(36)$ are the Ljung-Box (1978) tests for 36th order serial correlation and heteroskedasticity in the residuals and in the squared residuals, respectively; the test statistics are $\chi^2(36)$ distributed.

Table 4.32: The estimates of VEC models for Panamax vessels during the sample period of 2005.1.4-2010.12.24

	Period One: 2005.1.4-2008.8.29				*Period two:2008.9.1-2009.1.30*			
Routes	P2A		P3A		P2A		P3A	
Variables	Spot	FFA	Spot	FFA	Spot	FFA	Spot	FFA
$\alpha_{s,f}$	-0.0272** (-4.004)	-0.0125 (-1.046)	-0.0163* (-1.835)	0.011 (0.759)	-0.105** (-2.645)	0.073* (1.777)	-0.073** (-2.369)	0.052 (1.497)
ΔS_{t-1}	0.708** (14.814)	0.205** (2.371)	0.736** (13.939)	0.254** (3.145)	0.644** (5.969)	0.051 (0.947)	0.567** (6.649)	0.180* (1.925)
ΔS_{t-2}	-0.181** (-4.894)	-0.185** (-2.648)	-0.230** (-5.627)	-0.183** (-2.930)				
ΔF_{t-1}	0.249** (8.748)	0.415** (3.753)	0.281** (7.232)	0.474** (6.965)	0.338** (3.43)	0.729** (6.932)	0.454 (4.641)	0.448** (3.778)
ΔF_{t-2}	0.027 (1.312)	0.005 (0.097)	0.074** (2.286)	-0.050 (-0.846)				
Granger causality test	Spot→FFA	FFA→Spot	Spot→FFA	FFA→Spot	Spot→FFA	FFA→Spot	Spot→FFA	FFA→Spot
	10.4 [0.00]	148.26 [0.00]	17.98 [0.00]	131.74 [0.00]	0.897 [0.343]	11.063 [0.00]	3.71 [0.05]	18.22 [0.00]
J-B test	333.09 [0.00]	309.09 [0.00]	1406.51 [0.00]	898.08 [0.00]	36.536 [0.00]	264.27 [0.00]	107.97 [0.00]	1.09 [0.58]
$Q(36)$	45.186 [0.140]	19.650 [0.988]	45.229 [0.139]	38.741 [0.347]	11.473 [0.930]	14.517 [0.853]	14.76 [0.818]	23.164 [0.28]
$Q^2(36)$	164.82 [0.00]	198.35 [0.00]	206.96 [0.00]	151.60 [0.00]	41.268 [0.25]	16.082 [0.235]	16.28 [0.67]	20.199 [0.458]
$\bar{R}^2$	0.733	0.249	0.737	0.189	0.743	0.566	0.720	0.398

See notes to Table 4.31.

As a consequence, we may conclude that during the first sub period, the forward market informationally leads the spot market and dominates the price discovery process and may contain important information of predicting spot prices.

The evidence of the cointegration relationship between variables is mixed for the period since the financial crisis. During the second sub period, no cointegration relationship is investigated for C4 and C7, while for P2A and P3A, spot and forward prices are cointegrated. The finding of the forward market leading the spot market can still be found at both routes during this period, supported by the larger effect of forward returns on the spot market than those on the forward market and supported by the unidirectional Granger causality from the forward to the spot market at the 5% significance level.

During the third sub period, cointegration test is not made at routes of P2A and P3A, since both spot and forward prices are stationary in levels. While for C4 and C7, both forward prices and spot prices are cointegrated. The ECT coefficients of the spot and the forward equations are both significant with opposite signs. It implies both prices are thought to react to a shock to the system in order to reach the long-term equilibrium. Furthermore, parameters of the cross–market lags in the spot equation are larger than those in the forward equation. This may be interpreted as an indication of the forward market leading the spot market. The Granger causality tests indicate that there is a bi-directional relationship between forward and spot prices at the route C4, while the effect of lagged forward prices on current spot ones is stronger than that of lagged spot prices on current forward ones. On the route C7, forward prices Granger cause spot ones without the feedback effect at the 5% significance level.

Further explanation of the results

Based on the results we obtained from models, we may conclude that forward prices are more efficient than spot ones and daily spot prices are led informationally by forward ones. This finding is expected, since it is clear that forward prices reveal the information of market expectations with regards to future spot rates from the way prices of freight forward contracts are formed. The FFA prices may thereby contain more information about future spot rates than the current and past spot prices alone. An increase in forward prices always indicates a higher market expectation about future spot prices and vice versa. Changes in forward prices can also influence the market sentiment. In reality, market players, for instance, ship-owners and charterers, trading in the spot market always check daily FFA prices to make some changes to their expected spot prices. Additionally, forward prices are always adjusted due to changes in the market expectations or supply/demand changes in the spot market. Spot prices therefore can have some impact on future prices in some cases.

4.5. Forecasts

Freight rates or time charter rates have been a topic of interest in the shipping industry for a long time. Due to the ongoing uncertainty in the international shipping and especially the volatile nature of spot rates, quantitative analyses of spot rates or pricing the shipping freight market have always drawn much attention of researchers in the shipping community. The pioneer work can be found in Tinbergen(1959) and Zannetos (1966), and later on Wergeland(1981), Strandenes and Wergeland (1982) and Beenstock and Vergottis (1993) among others. These studies consist of attempts to model freight rates in terms of a supply and demand framework and to identify factors that determine freight rates. Since Beenstock and Vergottis(1993), researchers have turned their attention on examining the statistical properties of freight rates, and exploring further dynamic relations between shipping prices by using the reduced form autoregressive models. Examples are Veenstra and Franses (1997), Veenstra(1999), Kavussanos(1999, 2003), and Batchelor et al (2007) among others.

Various econometric models have been used to make the prediction of shipping spot prices in the previous research, including ARMA, VAR and VECM models. The forecast models, however, have their own application limitations, and there will never be a generalised model that can be applicable for predicting prices in different markets. Furthermore, the market has changed significantly and become more volatile and complex since 2003 compared to the market before, as mentioned in Lu Jing et al(2008). It is therefore worthwhile to re-investigate the dry bulk market to figure out the most important information, and to construct forecasting models which can provide superior results. In this section, the forecasting performance of various forecasting models and that of FFA prices will be investigated.

4.5.1. To forecast monthly spot rates on each route in each market

The main objective of this section is to set up forecasting models that can predict spot rates on four major routes for Capesize, Panamax and Handymax vessels for the N-step ahead. In this section, the indicator of one-month index change is invented and included into the forecasting models, which is very helpful in improving the prediction performance. Significant exogenous variables are filtered out as well and employed to yield better forecasting results. Then time series models and their extensions are employed and evaluated during two estimation periods, one is from Jan 1990 to June 2009, and the other runs from Jan 2003 to June 2009. All of these forecasting models are used to make the prediction of spot prices during the period of July 2009 to Dec 2010. The comparison of forecasting performance between various models is finally made trying to obtain superior forecasting models in the prediction of monthly spot rates for three types of vessels.

4.5.1.1. Data description

The dry bulk shipping market is generally divided into three sub-markets by ship size: the Capesize, the Panamax and the Handymax/Handy markets. Each size ship is involved in different trades and different routes. The majority of Capesize vessels are engaged in the transportation of iron-ore, mainly from Brazil and Australia, and also coal from Australia and South Africa. Panamax ships are used for iron ore exports from Brazil and Australia, coal exports from North America and Australia, grain exports from North America and Argentina, as well as bauxite and phosphate. Handymax/Handy vessels are used to transport grain from North America and Argentina to Africa and West Europe as well as minor bulks from all over the world. There are typical four main trading routes for these three main ship types, i.e. the transatlantic, the fronthaul, the transpacific and the backhaul. The route descriptions are reported in Table 4.10.

In order to model and forecast the spot prices in the spot freight market, monthly Time Charter Rates on Trip basis (TCT) on each route, equal to the time charter equivalents of voyage charter rates, are used in this section for estimation and forecast. The data set used consists of monthly TCT rates for dry bulk vessels, covering the period from Jan 1990 to Dec 2010, yielding a sample of 252 observations. The TCT rates for each size on the individual underlying trading routes are benchmark prices assessed based on the standard vessels on a daily basis by a panel of independent international shipbrokers. These figures are all obtained from Clarkson Research Studies. TCT rates on each route for each ship size are presented in Figures 4.17-4.19. It’s clearly revealed that prices have changed dramatically and trends are distinctly different after 2003, compared with the period before 2003, which may create structural breaks in the series during the whole period. Summary statistics of logarithmic monthly TCT rates during sample period are presented in Table 4.33.

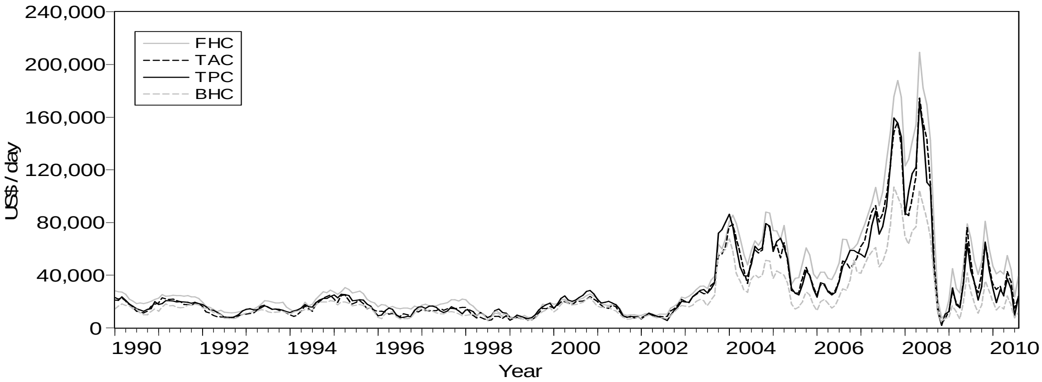

Figure 4.17: Monthly TCT rates at four routes for Capesize from Jan 1990 to Dec 2010.

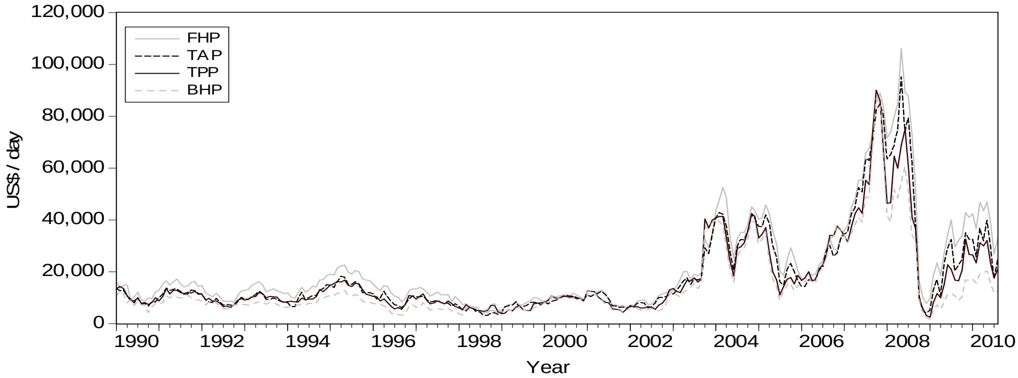

Figure 4.18: Monthly TCT rates at four routes for Panamax from Jan 1990 to Dec 2010.

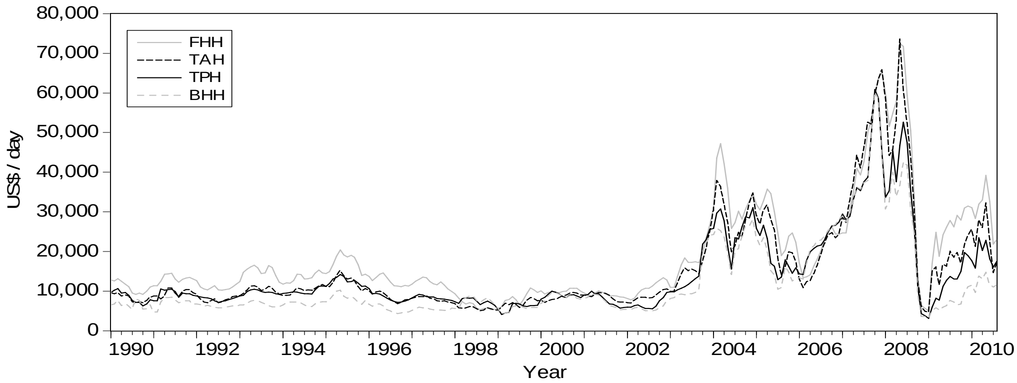

Figure 4.19: Monthly TCT rates at four routes for Handymax from Jan 1990 to Dec 2010.

Notes: FHC=Fronthaul Capesize, TAC=Transatlantic Capesize, TPC=Transpacific Capesize, BHC=backhaul Capesize, FHP=Fronthaul Panamax, TAP=Transatlantic Panamax, TPP=Transpacific Panamax, BHP=Backhaul Panamax, FHH=Fronthaul Handymax, TAH=Transatlantic Handymax, TPH=Transpacific Handymax, BHH=Backhaul Handymax

Additionally, daily Baltic Freight Index (BFI), Baltic Capesize Index (BCI), Baltic Panamax Index (BPI), Baltic Handymax Index (BHMI) are also collected from Baltic Exchange during 2nd Jan, 1990 to 24th Dec, 2010. Because BCI has first been published since April 1999, BFI was used before 1999 to construct a complete time series for Capesize during the sample period. BPI has been officially published since 21st Dec, 1998, before which, BFI was used to construct a time series for Panamax. A complete index series for Handymax vessels comprises BFI from Jan 1990 to Dec1996 and BHMI from Jan 1997 to Dec 2010. The Baltic indices for each ship size are utilized to make an indicator of market changes, which will be explained later.

Results of all price series in Table 4.33 show that during the sample period spot prices of Capesize vessels are more volatile than those of smaller ones, and prices of all three ship sizes fluctuate more in the second sub-period than those of the whole sample period. Excess kurtosis can be found in all price series, while there is no significant skewness on transpacific and backhaul routes for both Capesize and Panamax vessels during the whole sample period. Data with excess kurtosis tend to have distinct peak near mean and drop quickly. The Jarque and Bera (1980) tests indicate departures from normality for all series. The Ljung-Box Q(20) and $Q^2(20)$ statistics (Ljung-Box, 1978) on the first 20 lags of the sample autocorrelation function of the logarithmic first different series and of the squared series indicate the significant serial correlation and the existence of heteroskedasticity, respectively during the whole sample period. The existence of serial correlation in all series may result from the way ship-broking companies calculate the prices. As mentioned above, an assessment by the panelist is either made on an actual fixture or, in the absence of an actual fixture, made on the previous day’s level, which will induce autocorrelation in different rates. We use the Augmented Dicky-Fuller (ADF,1981) and Philips-Perron (PP,1988) unit root tests on the log levels and log-first differences of the price series to examine whether the series are stationary. The results show that all variables are non-stationary on the log-levels and stationary on the log first differences.

Table 4.33: Descriptive statistics of logarithmic first differences of TCT rates for Capesize, Panamax and Handymax

	N	Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Q(20)	$Q^2(20)$	ADF(lags)	PP	ADF(lags)	PP
									Lev	Lev	1st diffs	1st diffs
The whole sample period (Jan 1990 to Dec 2010)												
TAC	251	-0.0003	0.247	-0.760 [0.00]	9.098 [0.00]	406.53 [0.00]	84.16	234.95	-2.53(2)	-2.65	-12.36(1)	-11.42
FHC	251	-0.0001	0.206	-1.154 [0.00]	12.93 [0.00]	1068.91 [0.00]	105.15	164.86	-2.13(2)	-2.34	-12.34(1)	-10.01
TPC	251	-0.0011	0.296	-0.470 [0.00]	14.21 [0.00]	1302.45 [0.00]	71.86	196.80	-3.03(0)	-3.01	-11.87(2)	-14.92
BHC	251	-0.0020	0.257	-0.119 [0.44]	7.376 [0.00]	197.67 [0.00]	73.16	258.25	-2.92(2)	-3.02	-13.10(1)	-13.42
TAP	251	0.0019	0.205	-0.727 [0.00]	11.084 [0.00]	694.28 [0.00]	43.77	89.37	-2.74(1)	-2.41	-12.47(0)	-12.28
FHP	251	0.0018	0.171	-1.186 [0.00]	11.003 [0.00]	717.06 [0.00]	39.05	33.23	-2.38(1)	-2.05	-12.22(0)	-12.06
TPP	251	-0.0005	0.214	-0.103 [0.50]	12.748 [0.00]	978.38 [0.00]	39.26	68.65	-2.89(1)	-2.58	-12.89(0)	-12.75
BHP	251	-0.0016	0.224	-0.010 [0.95]	10.883 [0.00]	639.54 [0.00]	44.67	80.33	-3.01(1)	-2.41	-12.69(0)	-12.55
TAH	251	0.0022	0.157	0.351 [0.02]	20.159 [0.00]	3035.2 [0.00]	57.88	82.81	-2.75(1)	-2.29	-11.48(0)	-10.92
FHH	251	0.0018	0.151	0.544 [0.00]	25.169 [0.00]	5070.2 [0.00]	80.24	80.30	-3.06(1)	-2.40	-9.49(0)	-9.23
TPH	251	0.0009	0.149	-1.182 [0.00]	14.812 [0.00]	1493.5 [0.00]	67.75	100.70	-2.85(1)	-2.31	-11.16(0)	-10.77
BHH	251	0.0011	0.158	-1.324 [0.00]	14.756 [0.00]	1494.6 [0.00]	54.49	53.04	-2.74(1)	-2.02	-11.53(0)	-11.
The Second Sub-period (Jan 2003 to Dec 2010)												
TAC	96	-0.0002	0.305	-0.724 [0.00]	5.560 [0.00]	33.15 [0.00]	51.463	60.701	-2.79(2)	-2.84	-8.16(1)	-6.97
FHC	96	0.0018	0.302	-1.020 [0.00]	7.198 [0.00]	83.52 [0.00]	60.013	46.358	-2.76(2)	-2.84	-8.20(1)	-6.49
TPC	96	-0.0023	0.437	-0.422 [0.09]	7.690 [0.00]	87.06 [0.00]	46.807	57.841	-3.11(0)	-3.18	-8.96(0)	-9.76
BHC	96	-0.0071	0.368	-0.103 [0.68]	4.381 [0.00]	7.47 [0.04]	49.152	59.078	-3.24(1)	-2.66	-8.11(1)	-8.09
TAP	96	0.0070	0.282	-0.805 [0.00]	7.826 [0.00]	99.21 [0.00]	30.294	26.130	-3.19(1)	-2.82	-7.21(0)	-7.10
FHP	96	0.0078	0.223	-1.372 [0.00]	9.263 [0.00]	179.2 [0.00]	33.153	12.392	-3.26(1)	-2.77	-6.56(0)	-6.35
TPP	96	-0.0010	0.295	-0.206 [0.42]	8.889 [0.00]	133.6 [0.00]	26.757	23.17	-2.98(1)	-2.77	-7.53(0)	-7.53
BHP	96	-0.0048	0.303	-0.123 [0.63]	7.962 [0.00]	94.60 [0.00]	31.162	30.245	-2.71(1)	-2.48	-7.26(0)	-7.24
TAH	96	0.0047	0.238	0.223 [0.38]	9.718 [0.00]	173.8 [0.00]	29.239	23.135	-3.14(1)	-2.69	-7.01(0)	-6.97
FHH	96	0.0048	0.227	0.366 [0.15]	12.81 [0.00]	370.6 [0.00]	37.808	28.137	-3.23(1)	-2.88	-6.09(0)	-6.07
TPH	96	0.0025	0.218	-1.114 [0.00]	8.154 [0.00]	120.9 [0.00]	32.622	28.940	-2.88(1)	-2.58	-6.64(0)	-6.63
BHH	96	0.0016	0.219	-1.407 [0.00]	9.700 [0.00]	202.4 [0.00]	30.443	19.055	-2.44(1)	-2.18	-6.68(0)	-6.69

Notes:

♦ All the series are measured in logarithmic first differences. TAC, TAP and TAH mean logarithmic first differences of daily TCT rates for the Capesize, Panamax and Handymax, respectively on the transatlantic route; FHC, FHP and FHH for the Capesize, Panamax and Handymax on the fronthaul route; TPC, TPP and TPH for the Capesize, Panamax and Handymax on the transpacific route; BHC, BHP and BHH for the Capesize, Panamax and Handymax on the backhaul route.

♦ For the whole sample period, the 5% critical value for the ADF and PP tests is -2.87; The 1% critical value for the ADF and PP tests is -3.45. For the second sub-period, the 5% critical value for the ADF and PP tests is -2.89; The 1% critical value for the ADF and PP tests is -3.50.

4.5.1.2. Methodology

In this section, various forecasting models and procedures used in our study are presented and discussed. To identify models that provide superior forecasts of spot prices in the dry bulk market, several time series models are considered, including the ARIMA, ARIMAX, VAR, VARX, VECM and VECMX models, details of which are described in Appendix A.

ARIMA ($p,1,q$) model

The Box and Jenkins (1970) ARIMA model processes are combinations of auto regressive and moving average models. As results shown in Table 4.33 indicate that all prices series are stationary on the log first differences, all price series are transformed to be logarithmic first difference for the analysis. The current value of some series ΔX_t depends linearly on its own previous values plus a combination of current and previous values of a white noise error term. Generally speaking, an ARIMA ($p,1,q$) model will take the form as follows:

$$\Delta X_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i \Delta X_{t-i} + \sum_{j=0}^{q} \theta_j \varepsilon_{t-j} \qquad (4.29)$$

Where ΔX_t are changes in spot prices and ε_t are random error terms. The order of integration is determined by the Augmented Dickey-Fuller (ADF) test. Lag orders p and q can theoretically be determined using PACF and ACF. The Schwarz Bayesian Information Criterion (SBC, Schwarz, 1978) is used to choose the most appropriate model among adequate models.

An ARIMAX model is an autoregressive moving average (ARIMA) model for an endogenous dependent variable with additional explanatory exogenous variables. Bierens (1987) develops an estimation and testing methodology for such a model. The ARIMA part is considered as a special case of ARIMAX with no regressor by Greene (1990). Harvey (1990) and Franses (1991) treat the ARIMAX problem as an extension of ARIMA modelling because the disturbances are generated by an ARIMA ($p,1,q$) process.

In other words, an ARIMAX ($p,1,q,z$) model can be explicitly represented as

$$\Delta X_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i \Delta X_{t-i} + \sum_{k=1}^{s} \beta_k Z_{r,t-k} + \sum_{j=0}^{q} \theta_j \varepsilon_{t-j} \qquad (4.30)$$

Where ΔX_t are changes in spot prices; α_0 is the constant term, Z_t is the $r \times 1$ vector of exogenous variables, β_k is the $1 \times r$ vector of parameters, ε_t are random error terms.

The estimation of ARIMAX model should firstly ensure that the dependent variable ΔX_t should be stationary. Furthermore, the ARIMAX model requires that all exogenous variables also show stationary time series patterns. In comparison to the ARIMA model, the ARIMAX model takes the exogenous variables into account, so the forecasting method of the ARIMAX model does not solely depend on the historical data of its own endogenous variables.

VAR (p) model

The use of VAR models has been recommended by Sims (1980) as an efficient alternative to verify causal relationships in economic variables and to forecast their evolution. Given ΔX_t the vector of variables, the classical VAR model explains each variable by its own p past values and p past values of all other variables by the relation,

$$\Delta X_t = \phi_0 + \sum_{i=1}^{p} \phi_i \Delta X_{t-i} + \varepsilon_t \qquad (4.31)$$

Where ϕ_0 the deterministic component which can include a constant and seasonal dummies, the ϕ_i are $p \times p$ matrices, and ε_t is a zero-mean vector of white noise processes with positive definite contemporaneous covariance matrix Σ and zero covariance matrices at all other lags.

The potential advantage of the multivariate VAR model over the univariate ARIMA model is that it takes into account the information of other variables.

The VARX models refer to VAR models with additional exogenous variables.

$$\Delta X_t = \phi_0 + \sum_{i=1}^{p} \phi_i \Delta X_{t-i} + \sum_{j=1}^{q} \gamma_j Z_{r,t-j} + \varepsilon_t \quad (4.32)$$

Where ϕ_0 is the constant term, ϕ_i are $p \times p$ matrices, Z_t is the $(r \times 1)$ vector of exogenous variables, γ_j are $1 \times r$ parameter matrices, and ε_t are error terms.

VARX models should in principle be the better performer because they incorporate not only the endogenous dynamics, but also additional information from exogenous variables. Comparing the performance of VAR and VARX, we control for the dimensionality in order to determine the contribution of the inclusion of Z_t. The Schwarz Bayesian Information Criterion (SBC; Schwarz, 1978) is used to determine the lag length in VAR and VARX models and to select the most appropriate exogenous variables to be incorporated in VARX models. The vector Z_t is observed at the time of the forecast values produced, hence forecasts for exogenous variables are not necessary.

VECM (p) model

A cointegration test is used to investigate a long-run equilibrium relationship between variables. Engle and Granger (1987) demonstrate that if two non-stationary variables are cointegrated, the variables follow a well-specified error correction model (ECM), where the coefficient estimates, as well as the standard errors of the coefficients are consistent. The vector error correction modelling (VECM) framework, proposed by Johansen (1988), is preferred by researchers to investigate a cointegration relationship between variables due to its most reliable procedure.

Consider a VAR of order p ,

$$X_t = \phi_0 + A_1 X_{t-1} + A_2 X_{t-2} + \cdots + A_p X_{t-p} + \varepsilon_t \quad (4.33)$$

Where X_t is a k -vector of non-stationary $I(1)$ variables, and ε_t is a vector of innovations. We may rewrite this VAR as,

$$\Delta X_t = \phi_0 + \sum_{i=1}^{p-1} \Gamma_i \Delta X_{t-i} + \prod X_{t-1} + \varepsilon_t \quad (4.34)$$

Where Δ denotes the first difference operator, Γ and $\prod$ are coefficient matrices.

Granger's representation theorem asserts that if the coefficient matrix $\prod$ has a reduced rank $r < k$, then there exist $k \times r$ matrices α and β each with rank r , such that $\prod = \alpha\beta'$ and $\beta' X_t$ is $I(0)$. r is the number of cointegrating relations and each column of β is the cointegrating vector. The elements of α are known as the adjustment parameters in the VEC model. Johansen's method is to estimate the $\prod$ matrix from an unrestricted VAR and to test whether we can reject restrictions implied by the reduced rank of $\prod$.

A rather general VECM form that includes exogenous variables, is

$$\Delta y_t = \mu_t + \sum_{i=1}^{p} \Gamma_i \Delta y_{t-i} + \prod y_{t-1} + \sum_{j=1}^{q} \gamma_j Z_{r,t-j} + \varepsilon_t \qquad (4.35)$$

Where μ_t is the deterministic term, ϕ_i are $k \times k$ matrices, Z_t is the $r \times 1$ vector of exogenous variables, γ_j are $1 \times r$ parameter matrices and ε_t are error terms. The selection of exogenous variables into the VEC model is determined by the criterion employed in the VAR model.

The VECM specification contains information on both the short- and long-run adjustment to changes in X_t via the estimates of Γ and $\prod$, respectively. The VAR model here can be considered as a restricted version of the VECM in which the equilibrium correction term is dropped. The advantage of the VECM model in comparison to the univariate ARIMA and multivariate VAR models is that it takes into account both the short-run dynamics and the long-run relationship between variables.

4.5.1.3. Empirical analysis

As noted above, results of the unit root tests on log levels and log first differences of monthly TCT price series indicate that all variables are log-first difference stationary, all having a unit root on the log levels representation. This means that the first differences of spot prices should be used in the ARIMA and VAR models, while cointegration tests should be performed to ascertain the long-run relationship between variables if the VECM model is going to be used. Johansen's (1988) multivariate cointegration test results indicate that TCT rates at different routes are not cointegrated at the 10% significance level for three ship sizes. Results of cointegration tests can be available from authors upon request.

The non-existence of cointegration relationships between prices at four routes may be explained in two aspects. Firstly, interactions of shipping rates on four major trading routes are always changing under different market conditions. Specifically, on the one hand, if the demand in the Atlantic area is relatively higher enough to attract vessels currently operating in the Pacific to participate in the Atlantic market to make a profit, shipping rates during the Atlantic area will be influenced negatively by the increased tonnage supply and those in the Pacific could be improved by the reduced supply of vessels. On the other hand, when the market demand is strong for both the Atlantic and the Pacific markets, shipping prices during these two trading areas could be increased simultaneously and the switching activities between these two areas will not be significant. Furthermore, some ship-owners have preference to operate in certain trading areas, though vessels can run worldwide. So although shipping prices during major routes are interrelated, there will not be significant long-run relationships between variables.

Secondly, trading patterns are shifting during the sample period. China’s demand for iron ore has expanded tremendously since 2002, from less than 20% of the total seaborne trade, to around 70% of the total in 2010. China’s huge demand for raw materials and the increasing demand from other Asian countries such as South Korea and India, trigger much more active trading activities on the fronthaul and transpacific routes since 2003, compared to the previous period. Changes in trading activities at different trading areas may lead to changes in interactions of prices at each route.

Since there are no cointegration relationships between prices at different routes, the VECM is not employed in this section.

Forecasting models

Except for the VEC model, there are ARIMA, ARIMA-X, VAR, VAR-X models. Before employing these general models into analysis, some significant factors influencing the dry bulk market need to be investigated at first, so as to see which factors can be included into forecasting models to improve the forecasting performance.

- **Changes in the Baltic Indices**

The dry bulk shipping freight market is subject to a wide range of external variables including politics, the weather and wars. But it is fundamentally driven by the fleet supply, the commodity demand, bunker prices and the market sentiment. The first three factors have been investigated extensively in the previous research, examples are Beenstock and Vergottis (1993) among others. The importance of the market sentiment is stressed by Hampton M.J. (1990), who argues that in any market including the shipping market, participants are caught up in a struggle between fear and greed. The psychology of the crowd feeds upon itself until it reaches an extreme that cannot be sustained. Once the extreme is reached, too many decisions have been made out of emotion. The market sentiment or the market opinion can affect the freight market just as much as the actual supply and demand of ships and cargoes because as little as half of the demand side is known in a timely fashion.

Changes in market fundamentals, including the supply, the demand and the market sentiment during a specific period in the dry bulk shipping market can be reflected in the Baltic Indices of different ship sizes, namely, the BCI, the BPI and the BHMI. The daily BCI is the weighted average of voyage rates and time charter rates on major trading routes and it is the aggregate index of measuring shipping prices of Capesize vessels. The daily BPI and BHMI are the aggregate indices of measuring shipping prices of Panamax and Handymax vessels, respectively.

The change in the Baltic index not only signifies the change in the market fundamentals during the current period, but also contains information of the market future movement. It is often assumed that an increase in the Baltic index is indicative of an increasing demand for commodities as producers are buying more raw materials, such as iron ore, coal and coke. When shipments increase, economies tend to do well. While a decline in the Baltic index may indicate a decreasing demand and producers will slow down their production. Therefore, the change in the Baltic index may be often considered as a leading indicator of future economic growth or contraction. Apart from this, the market sentiment may persist for some time, so it can influence investors' views on the market future trends and their actions of chartering vessels. Consequently, the one-month change in the Baltic index is employed as an indicator of the market future movement.

In this section, one-month changes in the BCI, the BPI and the BHMI are utilized.

$$\Delta BCI_t = \sum_{i=1}^{n} \Delta BCI_{m-i} \tag{4.36}$$

$$\Delta BPI_t = \sum_{i=1}^{n} \Delta BPI_{m-i} \tag{4.37}$$

$$\Delta BHMI_t = \sum_{i=1}^{n} \Delta BHMI_{m-i} \tag{4.38}$$

Where ΔBCI_t, ΔBPI_t and $\Delta BHMI_t$ denote the total changes of the Baltic Indices in the Capesize, Panamax and Handymax segments at month t. ΔBCI_m, ΔBPI_m and ΔBHI_m are the daily changes of the Baltic Capesize Index, the Baltic Panamax Index and the Baltic Handymax Index, respectively. m is the last trading day of month t, and n is the total trading days of month t.

Because the one-month change in the Baltic Indices and shipping rates are interrelated, they are applied into the VAR and the VAR-X models to measure the interrelations between variables.

- **Macroeconomic indicators**

The demand for dry bulk carrier capacity is determined by the underlying demand for commodities transported in dry bulk carriers, which is influenced significantly by the industrial production. In addition to the industrial production, the exchange rate is also considered because shipping prices are all based on US dollars and they are influenced by changes in the value of the US dollar. Therefore, the industrial production and the exchange rate of the US dollar against other currencies need to be examined among many economic indicators to see their impacts on shipping prices.

Among industrial production indicators of many nations, the industrial production of OECD countries is selected, because it’s a major economic indicator of highly developed economies. Among a lot of exchange rate indicators, the US Dollar Index (USDX) is included into models. Furthermore, the EUR/USD exchange rate has the greatest weight of all currencies included in the US Dollar Index, the exchange rate of Euro against US dollar is examined as well.

According to Investor Glossary, the US Dollar Index (USDX) is an index (or measure) of the value of the United States dollar relative to a basket of foreign currencies. This basket consists of euro (EUR), Japanese yen (JPY), Pound sterling (GBP), Canadian dollar (CAN), Swedish krona (SEK), and Swiss franc (CHF). The US Dollar Index is a leading benchmark for the international value of the US dollar and the world's most widely-recognized and publicly-traded currency index. And it is also a great tool for measuring the global strength of the United States Dollar. The USDX figures during Jan 1990 to Dec 2010 are obtained from a futures company in China.

The exchange rate of EUR against USD can be influenced by the economic fundamentals between countries in the Euro area and the United States, whose economic performance has the direct impact on shipping industry. The euro was introduced to world financial markets as an accounting currency on 1 January 1999, replacing the former European Currency Unit (ECU) at a ratio of 1:1. As a result, the time series of the exchange rate during Jan 1990 to Dec 2010 comprise the exchange rate of ECU/USD from Jan 1990 to Dec 1998 and the exchange rate of EUR/USD from Jan 1999 to Dec 2010. Both the ECU/USD and EUR/USD figures are obtained from OANDA.

The Schwarz Bayesian Information Criterion (SBC; Schwarz, 1978) and the coefficient of determination ($\overline{R}^2$) are utilized to evaluate the inclusion of external variables into the models, which can reduce SBC and improve $\overline{R}^2$.

Estimation results

For evaluation purposes, the data are split into an in-sample estimation set and an out-of sample forecast set. In order to test whether the market since 2003 is significantly different from the market before, the in-sample estimation is made over two sample periods. Various models are estimated firstly over the whole period from Jan 1990 to June 2009, and then estimated again over the second period from Jan 2003 to June 2009 for all routes in three ship size markets. The period from July 2009 to Dec 2010 is then evaluated to make the independent out-of-sample N-period ahead of forecasts.

The results of ARIMA and ARIMAX models of spot TCT rates for four routes in three ship size markets are presented in the first two columns of Tables 4.34-4.39. The lag length for the autoregressive and moving average parts are chosen to minimize the Schwartz Bayesian Criterion (SBC; Schwartz, 1978). The lagged exogenous variables are selected based on the criterion of minimizing SBC and improving the coefficients of determination of equations. The lagged USDX is chosen for models estimated over the first sample period Jan 1990 to June 2009 for three types of vessels, and the lagged EUR/USD exchange rate is chosen as exogenous for models estimated over the second sample period Jan 2003 to June 2009 for Capesize and Panamax vessels. For models of Handymax vessels over the second sample period, the lagged USDX indicator is used as the exogenous variable. The lagged indicator of the industrial production of OECD does not exhibit additional significant impact on spot rates, they are consequently not incorporated into forecasting models.

All ARIMA and ARIMAX models seem to be well specified, as indicated by relevant diagnostic tests for autocorrelation and heteroskedasticity. For ARIMA models in both sample periods, it can be noted that the adjusted coefficients of determination for changes in spot rates on the transatlantic and the fronthaul are higher than those on the transpacific and the backhaul routes in Capesize and Panamax markets, indicating potentially the higher predictability of spot rates in the Atlantic area than that in the Pacific area. While in the Handymax market, the adjusted coefficients of determination on the fronthaul and transpacific routes are higher than those on the transatlantic and backhaul routes.

For ARIMAX models, the coefficients of lagged exogenous variable are broadly larger in magnitude at the transatlantic and the fronthaul routes than those at the other two routes for three types of vessels. This means spot rates in the Atlantic seem to be more sensitive to macroeconomic situations than those in the Pacific area. In light of exogenous variables incorporated, ARIMAX models seem to have greater predictive power than ARIMA models, since both the coefficient of determination and SBC have been improved.

The last two columns in Tables 4.34-4.39 present the estimates of coefficients of the VAR and VARX models. These are similar to the ARIMA and ARIMAX models in terms of the appropriate number of lag lengths used and the diagnostic tests. As expected, the adjusted coefficients of determination of the VAR and VARX models are higher than those of the ARIMA and ARIMAX models due to the use of extra information, namely, the lagged spot rates on different routes and the inclusion of the indicator of one-month Baltic index change for each ship size. The incorporation of the indicator of one-month index change has substantially improved the explanatory power of models, see Table 4.40. Just as mentioned above, the expectation on the future market and the market sentiment will significantly influence the behavior of market players and subsequently affect the price movement.

For VAR models, prices on four routes are influenced each other through changes of tonnage in a specific trading area or demand shifts. However, there are no unified conclusions about interrelations of prices on four routes for three markets, because each market moves diversely in the short run, affected by various market disturbances. Furthermore, results in the whole estimation period are not consistent with results in the second estimation period, which may be partly explained by the shifting market situations.

The lagged change in the one-month index change has a significantly positive impact on the price changes on all routes for all three markets. Specifically, the price change at the current period will be directly affected by the cumulative index change in the previous period, which may contain information of the future market movement. Furthermore, the coefficients of the lagged indicator of one-month index change are greater in magnitude for bigger ships. This means the Capesize market will suffer most from changes in the market expectations and the market sentiment, while the Handymax the least.

For VARX models, the USDX is incorporated into models during the whole estimation period and the EUR/USD exchange rate is included into models for the second estimation period in most cases with the exception of Handymax models. The adjusted coefficients of determination in the VARX model are broadly greater than those in the VAR model in all cases due to more information incorporated, signifying the higher predictability of the VARX model.

Table 4.34: Estimates of forecasting models for Capesize vessels during the period Jan 1990 to Jun 2009

	ARIMA				ARIMAX				VAR					VARX				
	ΔTAC_t	ΔFHC_t	ΔTPC_t	ΔBHC_t	ΔTAC_t	ΔFHC_t	ΔTPC_t	ΔBHC_t	ΔTAC_t	ΔFHC_t	ΔTPC_t	ΔBHC_t	ΔBCI_t	ΔTAC_t	ΔFHC_t	ΔTPC_t	ΔBHC_t	ΔBCI_t
ΔTAC_{t-1}	0.449** (3.178)				0.402** (3.03)				-0.239 (-1.598)	0.009 (0.072)	-0.248 (-1.136)	-0.283* (-1.795)	-0.157 (-0.977)	-0.277* (-1.871)	-0.007 (-0.054)	-0.272 (-1.287)	-0.277* (-1.772)	-0.178 (-1.128)
ΔFHC_{t-1}		0.546** (3.935)				0.504** (3.793)			0.146 (0.728)	-0.053 (-0.281)	0.230 (0.784)	0.257 (1.262)	0.121 (0.619)	0.165 (0.845)	-0.048 (-0.340)	0.229 (1.114)	0.254 (1.258)	0.128 (0.727)
ΔTPC_{t-1}			0.159 (1.023)				0.136 (1.232)		-0.012 (-0.073)	0.105 (0.663)	-0.415 (-1.548)	-0.082 (0.158)	0.072 (0.472)	-0.015 (-0.099)	0.103 (1.361)	-0.458** (-2.277)	-0.082 (-0.841)	0.07 (0.745)
ΔBHC_{t-1}				0.309** (2.321)				0.291** (2.258)	-0.274* (-1.841)	-0.364** (-2.756)	-0.082 (-0.424)	-0.224 (-1.188)	-0.284 (-1.627)	-0.264** (-1.794)	-0.361** (-4.237)	-0.082 (-0.661)	-0.225 (1.197)	-0.267** (-2.290)
ΔTAC_{t-2}	-0.230** (-2.438)				-0.216** (2.307)													
ΔFHC_{t-2}		-0.309** (-2.832)				-0.295** (-2.82)												
ΔTPC_{t-2}			-0.268** (-2.037)				-0.269** (-2.047)											
ΔBHC_{t-2}				-0.218* (-1.964)				-0.217* (-1.925)										
ΔBCI_{t-1}									1.198** (9.491)	0.943** (7.385)	1.392** (5.865)	1.114** (7.352)	0.542** (3.109)	1.184** (9.822)	0.932** (8.040)	1.382** (5.637)	1.116** (7.357)	0.522** (3.275)
$\Delta USDX_{t-1}$					-1.853** (-2.56)	-1.432** (-2.45)	-1.378 (-1.436)	-0.97 (-1.252)						-1.183** (-2.097)	-0.977* (-2.138)	-0.018 (-0.027)	0.143 (0.246)	-1.348** (-2.378)
$\bar{R}^2$	0.175	0.247	0.089	0.103	0.194	0.264	0.096	0.106	0.526	0.499	0.463	0.443	0.146	0.535	0.509	0.462	0.440	0.166
AIC	-0.247	-0.679	0.174	-0.135	-0.269	-0.699	0.171	-0.134	-0.796	-1.080	-0.349	-0.602	-0.643	-0.819	-1.109	-0.347	-0.593	-0.677
SC	-0.217	-0.649	0.204	-0.105	-0.225	-0.655	0.21	-0.089	-0.722	-1.005	-0.274	-0.528	-0.568	-0.760	-1.065	-0.272	-0.504	-0.632
$Q(20)$	28.23 [0.104]	23.61 [0.260]	15.76 [0.731]	14.69 [0.794]	25.793 [0.173]	22.633 [0.307]	13.983 [0.87]	14.352 [0.812]	25.36 [0.201]	26.27 [0.158]	22.30 [0.324]	25.48 [0.183]	20.28 [0.441]	25.298 [0.190]	25.599 [0.179]	22.386 [0.320]	25.688 [0.176]	20.691 [0.426]
$Q^2(20)$	203.92 [0.00]	125.67 [0.00]	147.13 [0.00]	151.98 [0.00]	191.88 [0.00]	108.34 [0.00]	141.08 [0.00]	152.11 [0.00]	163.45 [0.00]	213.56 [0.00]	81.42 [0.00]	56.03 [0.00]	109.29 [0.00]	151.63 [0.00]	209.66 [0.00]	89.259 [0.00]	56.483 [0.00]	94.486 [0.00]

Notes:

- All the series are measured in logarithmic first differences. ΔTAC_t, ΔFHC_t, ΔTPC_t and ΔBHC_t mean logarithmic first differences of TCT rates for the Capesize on the transatlantic, the fronthaul, the transpacific and the backhaul route
- $\Delta USDX_t$ means the logarithmic first difference of monthly US Dollar index; $\Delta RATE_t$ is the logarithmic first difference of monthly exchange rate of EUR against USD.
- ΔBCI_t means monthly change of Baltic Capesize Index.
- Figures in parenthesis (·) means t-statistics, adjusted using the White (1980) heteroskedasticity consistent variance-covariance matrix. * and ** denote significance at the 10% and 5% levels, respectively. Figures in quare brackets [·] indicate exact significance levels
- Q(20) and $Q^2(20)$ are the Ljung and Box (1978) Q statistics on the first 20 lags of the sample autocorrelation function of the raw series and of the squared series; these tests are distributed as $\chi^2(20)$.The critical values are 37.56 and 31.41 for the 1% and 5% levels, respectively.

Table 4.35: Estimates of forecasting models for Capesize vessels during the period Jan 2003 to Jun 2009

	ARIMA				ARIMAX				VAR					VARX				
	ΔTAC_t	ΔFHC_t	ΔTPC_t	ΔBHC_t	ΔTAC_t	ΔFHC_t	ΔTPC_t	ΔBHC_t	ΔTAC_t	ΔFHC_t	ΔTPC_t	ΔBHC_t	ΔBCI_t	ΔTAC_t	ΔFHC_t	ΔTPC_t	ΔBHC_t	ΔBCI_t
ΔTAC_{t-1}	0.593** (3.271)				0.449** (2.817)				-0.442 (-1.141)	-0.080 (-0.224)	-0.922 (-1.643)	-0.619* (-1.692)	-0.468 (-0.908)	-0.401 (-1.194)	-0.036 (-0.117)	-0.749 (-1.412)	-0.529 (-1.444)	-0.421 (-0.999)
ΔFHC_{t-1}		0.633** (6.02)				0.478** (4.457)			0.302 (0.869)	-0.016 (-0.047)	0.809 (1.555)	0.616* (1.788)	0.352 (0.721)	0.268 (0.846)	-0.052 (-0.177)	0.799 (1.577)	0.622* (1.817)	0.313 (0.789)
ΔTPC_{t-1}			0.127 (1.02)				-		0.050 (0.262)	0.168 (0.925)	-0.507 (-1.633)	-0.170 (-1.276)	0.140 (0.823)	-0.019 (-0.155)	0.095 (0.826)	-0.635** (-2.596)	-0.224 (-1.648)	0.060 (0.388)
ΔBHC_{t-1}				0.300 (1.626)				0.211 (1.202)	-0.556** (-3.111)	-0.659** (-3.769)	-0.333 (-1.529)	-0.527** (-3.051)	-0.590** (-2.578)	-0.553** (-3.488)	-0.641** (-6.012)	-0.419** (-2.242)	-0.579** (-3.329)	-0.675** (-5.210)
ΔTAC_{t-2}	-0.361** (-3.018)				-0.340** (-2.724)													
ΔFHC_{t-2}		-0.417** (-3.876)				-0.399** (-3.972)												
ΔTPC_{t-2}			-0.308* (-1.980)				-0.300* (-1.847)											
ΔBHC_{t-2}				-0.197 (-1.252)				-0.231 (-1.305)										
ΔBCI_{t-1}									1.497** (8.508)	1.242** (6.803)	1.911** (5.882)	1.552** (10.453)	0.910** (3.670)	1.439** (9.438)	1.207** (8.102)	1.914** (6.290)	1.574** (10.508)	0.875** (5.657)
$\Delta RATE_{t-1}$					4.084** (3.01)	4.032** (3.543)	4.656 (1.463)	2.958* (1.746)						3.474** (3.795)	3.766** (3.913)	3.673** (2.931)	1.171 (1.106)	4.072** (3.452)
$\bar{R}^2$	0.277	0.324	0.103	0.096	0.345	0.413	0.157	0.111	0.672	0.619	0.637	0.667	0.287	0.721	0.693	0.676	0.672	0.382
AIC	0.405	0.079	1.034	0.668	0.319	-0.049	0.958	0.65	-0.347	-0.458	0.153	-0.307	0.082	-0.521	-0.685	0.064	-0.300	-0.073
SC	0.466	0.139	1.094	0.728	0.410	-0.040	1.01	0.741	-0.196	-0.307	0.305	-0.156	0.233	-0.400	-0.563	0.273	-0.087	0.047
$Q(12)$	16.605 [0.165]	8.235 [0.766]	8.29 [0.762]	7.43 [0.83]	17.89 [0.119]	8.10 [0.769]	7.37 [0.83]	7.36 [0.833]	16.166 [0.166]	18.65 [0.096]	9.62 [0.649]	14.855 [0.249]	8.859 [0.715]	11.211 [0.511]	15.22 [0.229]	11.075 [0.523]	14.564 [0.266]	7.726 [0.806]
$Q^2(12)$	64.745 [0.00]	27.457 [0.00]	47.94 [0.00]	42.32 [0.00]	51.52 [0.00]	21.78 [0.04]	41.27 [0.00]	45.30 [0.00]	50.205 [0.00]	43.93 [0.00]	39.811 [0.00]	9.485 [0.661]	24.761 [0.02]	27.491 [0.007]	26.816 [0.008]	36.84 [0.00]	8.905 [0.7111]	22.841 [0.03]

Notes:

- Q(12) and $Q^2(12)$ are the Ljung and Box (1978) Q statistics on the first 12 lags of the sample autocorrelation function of the raw series and of the squared series; these tests are distributed as $\chi^2(12)$ .The critical values are 26.22 and 21.03 for the 1% and 5% levels, respectively
- See other notes to Table 4.34.

Table 4.36: Estimates of forecasting models for Panamax vessels during the period Jan 1990 to Jun 2009

	ARIMA				ARIMAX				VAR					VARX				
	ΔTAP_t	ΔFHP_t	ΔTPP_t	ΔBHP_t	ΔTAP_t	ΔFHP_t	ΔTPP_t	ΔBHP_t	ΔTAP_t	ΔFHP_t	ΔTPP_t	ΔBHP_t	ΔBPI_t	ΔTAP_t	ΔFHP_t	ΔTPP_t	ΔBHP_t	ΔBPI_t
ΔTAP_{t-1}	0.277** (2.747)				0.238** (2.516)				-0.359** (-2.256)	0.119 (1.006)	0.132 (0.852)	-0.121 (-0.737)	-0.076 (-0.518)	-0.377** (-2.333)	0.151 (1.384)	0.164 (1.055)	-0.128 (-0.731)	-0.095 (-0.665)
ΔFHP_{t-1}		0.279** (4.387)				0.247** (3.937)			0.279* (1.656)	-0.186 (-1.315)	-0.297* (-1.784)	-0.169 (-0.866)	0.048 (0.348)	0.311* (1.793)	-0.225* (-1.764)	-0.361** (-2.68)	-0.277* (-1.753)	0.083 (0.486)
ΔTPP_{t-1}			0.207** (2.945)				0.182** (2.646)		-0.573** (-3.107)	-0.419** (-2.957)	-0.136 (-0.679)	0.189 (0.966)	-0.240 (-1.442)	-0.575** (-3.144)	-0.295** (-4.591)	-0.136 (-0.679)	0.232 (1.030)	-0.253* (-1.417)
ΔBHP_{t-1}				0.211** (2.179)				0.181* (1.907)	0.227 (1.367)	0.123 (1.053)	-0.160 (-0.809)	-0.286* (-1.772)	0.008 (0.062)	0.215 (1.312)	0.116 (0.997)	-0.259** (-2.198)	-0.337 (-1.551)	-0.005 (-0.037)
ΔBPI_{t-1}									1.079** (6.664)	0.849** (10.732)	1.052** (5.571)	1.037** (9.492)	0.536** (2.245)	1.041** (6.543)	0.817** (10.421)	1.035** (5.467)	0.998** (5.285)	0.479** (5.146)
$\Delta USDX_{t-1}$					-2.089** (-3.47)	-1.614** (-3.146)	-1.342** (-2.067)	-1.539** (-2.22)						-1.454** (-2.87)	-0.926** (-2.15)	-0.438 (-0.795)	-0.600 (-1.029)	-1.572** (3.092)
$\bar{R}^2$	0.076	0.0767	0.042	0.044	0.118	0.109	0.054	0.058	0.425	0.408	0.398	0.360	0.129	0.445	0.417	0.399	0.372	0.169
AIC	-0.459	-0.779	-0.289	-0.177	-0.506	-0.814	-0.302	-0.191	-0.921	-1.210	-0.741	-0.564	-0.799	-0.951	-1.225	-0.747	-0.566	-0.855
SC	-0.444	-0.764	-0.274	-0.162	-0.476	-0.785	-0.272	-0.162	-0.847	-1.136	-0.667	-0.490	-0.725	-0.862	-1.152	-0.687	-0.493	-0.811
$Q(20)$	17.446 [0.624]	15.719 [0.734]	24.201 [0.234]	22.792 [0.299]	16.763 [0.682]	18.562 [0.556]	25.546 [0.181]	25.234 [0.193]	31.27 [0.054]	27.05 [0.134]	25.31 [0.190]	22.42 [0.318]	29.488 [0.079]	27.822 [0.114]	27.267 [0.128]	26.80 [0.141]	21.784 [0.352]	30.597 [0.061]
$Q^2(20)$	73.914 [0.00]	23.143 [0.282]	53.421 [0.00]	51.875 [0.00]	65.568 [0.00]	22.085 [0.336]	53.432 [0.00]	51.606 [0.00]	59.454 [0.00]	26.76 [0.14]	48.96 [0.00]	36.35 [0.00]	99.515 [0.00]	50.387 [0.00]	23.870 [0.248]	48.99 [0.00]	36.471 [0.00]	100.67 [0.00]

Notes: ΔTAP_t, ΔFHP_t, ΔTPP_t ΔBHP_t mean logarithmic first differences of monthly TCT rates for the Panamax on the transatlantic, the fronthaul, the transpacific and the backhaul route. ΔBPI_t is the monthly change of Baltic Panamax Index. See other notes to Table 4.34.

Table 4.37: Estimates of forecasting models for Panamax vessels during the period Jan 2003 to Jun 2009

	ARIMA				ARIMAX				VAR					VARX				
	ΔTAP_t	ΔFHP_t	ΔTPP_t	ΔBHP_t	ΔTAP_t	ΔFHP_t	ΔTPP_t	ΔBHP_t	ΔTAP_t	ΔFHP_t	ΔTPP_t	ΔBHP_t	ΔBPI_t	ΔTAP_t	ΔFHP_t	ΔTPP_t	ΔBHP_t	ΔBPI_t
ΔTAP_{t-1}	0.360** (3.373)				0.237** (2.148)				-0.330 (-0.997)	-0.071 (-0.268)	0.256 (0.639)	0.189 (0.448)	-0.063 (-0.142)	-0.234 (-1.40)	-0.162 (-0.659)	0.227 (0.562)	0.169 (0.397)	-0.198 (-0.522)
ΔFHP_{t-1}		0.42** (4.029)				0.295** (2.803)			0.250 (0.614)	0.155 (0.478)	-0.331 (-0.672)	-0.399 (-0.769)	-0.036 (-0.066)	0.281 (0.737)	0.181 (0.604)	-0.323 (-0.653)	-0.394 (-0.753)	0.008 (0.016)
ΔTPP_{t-1}			0.263** (2.374)				0.203* (1.761)		-0.842 (1.705)	-1.122** (-2.856)	-0.417 (-0.698)	-0.133 (-0.211)	-0.204 (-0.311)	-0.435** (-1.27)	-0.449** (-2.476)	-0.496** (-2.023)	-0.087 (-0.137)	0.143 (0.233)
ΔBHP_{t-1}				0.281** (2.574)				0.228* (1.99)	0.343 (0.807)	0.604* (1.785)	-0.057 (-0.111)	-0.168 (0.309)	-0.206 (-0.367)	0.133 (0.33)	-0.425 (1.341)	-0.113 (-0.217)	-0.338 (-0.754)	-0.393** (0.95)
ΔBPI_{t-1}									1.237** (9.095)	0.994** (9.178)	1.132** (6.88)	1.139** (6.571)	0.763** (4.233)	1.172** (9.159)	0.888** (9.318)	1.115** (6.694)	1.055** (6.409)	0.696** (4.026)
$\Delta RATE_{t-1}$					3.519** (2.883)	3.114** (3.276)	2.251 (1.634)	2.038 (1.42)						2.815** (3.368)	2.478** (3.634)	0.752 (0.694)	0.496 (0.45)	3.911** (3.618)
$\bar{R}^2$	0.127	0.171	0.068	0.079	0.202	0.264	0.087	0.091	0.590	0.613	0.490	0.477	0.214	0.647	0.672	0.503	0.484	0.342
AIC	0.201	-0.249	0.429	0.497	0.123	-0.356	0.420	0.496	-0.505	-0.961	-0.125	-0.020	0.058	-0.669	-1.154	-0.176	-0.058	-0.134
SC	0.232	-0.219	0.459	0.527	0.184	-0.296	0.481	0.556	-0.354	-0.810	0.027	0.131	0.209	-0.549	-1.106	-0.086	0.033	-0.013
$Q(12)$	7.455 [0.826]	9.651 [0.649]	12.41 [0.413]	11.742 [0.467]	7.074 [0.853]	9.117 [0.693]	14.05 [0.297]	13.736 [0.318]	29.32 [0.003]	24.08 [0.02]	6.64 [0.88]	7.16 [0.847]	16.76 [0.159]	21.63 [0.042]	16.69 [0.162]	6.019 [0.915]	7.21 [0.844]	11.35 [0.493]
$Q^2(12)$	24.257 [0.02]	8.102 [0.777]	16.65 [0.163]	15.715 [0.265]	22.13 [0.036]	9.74 [0.639]	15.47 [0.217]	13.91 [0.302]	31.47 [0.002]	17.74 [0.12]	16.34 [0.176]	17.20 [0.142]	17.12 [0.145]	38.15 [0.00]	28.20 [0.003]	19.634 [0.075]	16.393 [0.174]	13.117 [0.361]

Notes:

- Q(12) and $Q^2(12)$ are the Ljung and Box (1978) Q statistics on the first 12 lags of the sample autocorrelation function of the raw series and of the squared series; these tests are distributed as $\chi^2(12)$ .The critical values are 26.22 and 21.03 for the 1% and 5% levels, respectively
- See other notes to Table 4.34.

Table 4.38: Estimates of forecasting models for Handymax vessels during the period Jan 1990 to Jun 2009

	ARIMA				ARIMAX				VAR					VARX				
	ΔTAH_t	ΔFHH_t	ΔTPH_t	ΔBHH_t	ΔTAH_t	ΔFHH_t	ΔTPH_t	ΔBHH_t	ΔTAH_t	ΔFHH_t	ΔTPH_t	ΔBHH_t	$\Delta BHMI_t$	ΔTAH_t	ΔFHH_t	ΔTPH_t	ΔBHH_t	$\Delta BHMI_t$
ΔTAH_{t-1}	0.355** (2.887)				0.327** (3.044)				0.093 (0.581)	0.121 (0.815)	-0.336** (-2.339)	-0.419** (-2.646)	-0.136 (-0.653)	0.075 (0.481)	0.109 (0.742)	-0.348** (-2.442)	-0.432** (-2.752)	-0.160 (-0.786)
ΔFHH_{t-1}		0.435** (3.961)				0.418** (7.049)			-0.127 (-0.816)	0.025 (0.169)	0.091 (0.645)	-0.030 (-0.195)	0.141 (0.691)	-0.112 (-0.729)	0.035 (0.242)	0.101 (0.726)	-0.018 (-0.121)	0.162 (0.814)
ΔTPH_{t-1}			0.367** (2.678)				0.345** (2.687)		-0.356* (-2.323)	-0.314** (-2.192)	0.145 (1.052)	0.212 (1.388)	0.037 (0.185)	-0.372** (-2.467)	-0.325** (-2.282)	0.135 (0.982)	0.199 (1.321)	0.015 (0.074)
ΔBHH_{t-1}				0.323** (2.306)				0.298** (2.279)	0.333** (2.578)	0.163* (1.349)	-0.084 (-0.718)	-0.023 (-0.18)	0.036 (0.215)	0.321** (2.531)	0.155 (1.295)	-0.091 (-0.792)	-0.032 (-0.251)	0.020 (0.121)
$\Delta BHMI_{t-1}$									0.539** (7.342)	0.569** (8.286)	0.688** (10.386)	0.705** (9.646)	0.103 (1.071)	0.539** (7.463)	0.568** (8.346)	0.688** (10.474)	0.705** (9.727)	0.102 (1.085)
$\Delta USDX_{t-1}$					-1.332** (-2.906)	-0.968** (-2.222)	-0.856* (-1.936)	-1.038** (-2.105)						-1.059** (-2.614)	-0.665** (-1.739)	-0.652** (-1.772)	-0.813** (-2.267)	-1.275** (-2.403)
$\bar{R}^2$	0.126	0.1887	0.134	0.104	0.154	0.202	0.144	0.118	0.317	0.400	0.411	0.362	0.05	0.340	0.410	0.421	0.373	0.06
AIC	-1.045	-1.126	-1.114	-0.963	-1.073	-1.138	-1.122	-0.975	-1.274	-1.411	-1.482	-1.285	-0.734	-1.305	-1.423	-1.495	-1.299	-0.776
SC	-1.029	-1.111	-1.099	-0.948	-1.043	-1.108	-1.092	-0.945	-1.200	-1.337	-1.407	-1.211	-0.664	-1.216	-1.333	-1.406	-1.210	-0.687
$Q(20)$	26.224 [0.159]	27.624 [0.119]	29.70 [0.075]	28.105 [0.107]	26.762 [0.142]	29.603 [0.075]	33.061 [0.033]	30.126 [0.065]	33.05 [0.05]	32.29 [0.05]	19.37 [0.498]	20.934 [0.401]	25.947 [0.168]	31.90 [0.04]	32.71 [0.05]	20.87 [0.405]	21.78 [0.352]	19.514 [0.077]
$Q^2(20)$	55.062 [0.00]	31.541 [0.048]	94.382 [0.00]	48.932 [0.00]	43.593 [0.00]	27.054 [0.134]	100.48 [0.00]	52.522 [0.00]	50.108 [0.00]	26.36 [0.154]	49.278 [0.00]	22.186 [0.33]	8.688 [0.986]	38.72 [0.00]	21.478 [0.37]	46.74 [0.00]	22.44 [0.319]	8.42 [0.750]

Notes: ΔTAH_t, ΔFHH_t, ΔTPH_t ΔBHH_t mean logarithmic first differences of monthly TCT rates for the Handymax on the transatlantic, the fronthaul, the transpacific and the backhaul route. $\Delta BHMI_t$ is the monthly change of Baltic Handymax Index. See other notes to Table 4.34.

Table 4.39: Estimates of forecasting models for Handymax vessels during the period Jan 2003 to Jun 2009

	ARIMA				ARIMAX				VAR					VARX				
	ΔTAH_t	ΔFHH_t	ΔTPH_t	ΔBHH_t	ΔTAH_t	ΔFHH_t	ΔTPH_t	ΔBHH_t	ΔTAH_t	ΔFHH_t	ΔTPH_t	ΔBHH_t	$\Delta BHMI_t$	ΔTAH_t	ΔFHH_t	ΔTPH_t	ΔBHH_t	$\Delta BHMI_t$
ΔTAH_{t-1}	0.358** (3.363)				0.278** (2.702)				0.158 (0.471)	0.263 (0.849)	-0.415 (-1.449)	-0.467 (-1.614)	0.030 (0.587)	0.109 (0.337)	0.227 (0.745)	-0.419** (-1.782)	-0.432** (-1.786)	-0.007 (-0.02)
ΔFHH_{t-1}		0.441** (4.306)				0.386** (3.783)			-0.292 (-0.859)	-0.195 (-0.622)	0.123 (0.427)	0.009 (0.031)	-0.039 (-0.075)	-0.191 (-0.576)	-0.119 (-0.385)	0.203 (0.717)	0.087 (0.03)	0.085 (0.206)
ΔTPH_{t-1}			0.399** (3.827)				0.318** (2.743)		-0.609 (-1.497)	-0.393 (-1.048)	0.289 (0.837)	0.275 (0.787)	0.541 (1.001)	-0.666** (-1.525)	-0.386 (-1.049)	0.305 (0.881)	0.299 (0.828)	0.656 (1.294)
ΔBHH_{t-1}				0.384** (3.667)				0.284** (2.378)	0.663* (1.829)	0.299 (0.896)	-0.234 (-0.759)	-0.093 (-0.298)	-0.284 (-0.594)	0.392** (1.654)	0.164 (0.489)	-0.432 (-1.232)	-0.281 (-0.71)	-0.68 (-1.473)
$\Delta BHMI_{t-1}$									0.592** (4.639)	0.614** (5.218)	0.746** (6.881)	0.754** (6.868)	-0.412** (-3.589)	0.631** (4.788)	0.707** (5.312)	0.781** (7.065)	0.786** (7.037)	-0.482 (-4.411)
$\Delta USDX_{t-1}$					3.281** (3.326)	2.272** (2.352)	-1.889 (-1.548)	-2.123* (-1.681)						-2.874** (-2.462)	-2.143** (-1.963)	-2.267** (-2.27)	-2.221** (-2.194)	-4.942** (-3.387)
$\bar{R}^2$	0.128	0.192	0.159	0.149	0.228	0.238	0.175	0.169	0.358	0.439	0.469	0.459	0.128	0.456	0.505	0.512	0.503	0.237
AIC	-0.088	-0.193	-0.259	-0.241	-0.198	-0.237	-0.264	-0.262	-0.345	-0.507	-0.669	-0.646	0.131	-0.524	-0.656	-0.763	-0.731	0.009
SC	-0.058	-0.162	-0.229	-0.211	-0.138	-0.177	-0.204	-0.192	-0.194	-0.356	-0.518	-0.494	0.282	-0.403	-0.566	-0.612	-0.580	0.190
$Q(12)$	9.986 [0.617]	11.341 [0.500]	12.495 [0.407]	9.964 [0.619]	10.423 [0.579]	12.290 [0.423]	13.838 [0.311]	11.448 [0.491]	19.197 [0.084]	18.057 [0.114]	10.854 [0.541]	11.683 [0.471]	10.655 [0.559]	19.698 [0.075]	17.858 [0.12]	11.499 [0.487]	13.497 [0.334]	18.298 [0.107]
$Q^2(12)$	14.058 [0.297]	8.300 [0.686]	18.360 [0.105]	11.270 [0.506]	8.629 [0.734]	7.141 [0.894]	23.350 [0.025]	13.179 [0.356]	14.211 [0.287]	8.555 [0.740]	11.688 [0.471]	5.238 [0.95]	5.0211 [0.96]	7.13 [0.849]	4.088 [0.982]	17.469 [0.133]	7.120 [0.850]	16.68 [0.162]

Notes:

- Q(12) and $Q^2(12)$ are the Ljung and Box (1978) Q statistics on the first 12 lags of the sample autocorrelation function of the raw series and of the squared series; these tests are distributed as $\chi^2(12)$ .The critical values are 26.22 and 21.03 for the 1% and 5% levels, respectively
- See other notes to Table 4.34.

Table 4.40: The explanatory power of the indicator of one-month index change in the VAR model

	VAR without the indicator				VAR with the indicator			
Capesize								
	ΔTAC_t	ΔFHC_t	ΔTPC_t	ΔBHC_t	ΔTAC_t	ΔFHC_t	ΔTPC_t	ΔBHC_t
$\bar{R}^2$	0.353	0.344	0.303	0.302	0.767	0.725	0.752	0.736
AIC	0.367	0.122	0.840	0.469	-0.633	-0.727	-0.172	-0.482
SC	0.609	0.363	1.082	0.711	-0.331	-0.425	0.130	-0.180
Panamax								
	ΔTAP_t	ΔFHP_t	ΔTPP_t	ΔBHP_t	ΔTAP_t	ΔFHP_t	ΔTPP_t	ΔBHP_t
$\bar{R}^2$	0.138	0.177	0.171	0.179	0.590	0.613	0.490	0.477
AIC	0.227	-0.219	0.350	0.419	-0.505	-0.961	-0.125	-0.020
SC	0.347	-0.098	0.471	0.540	-0.354	-0.810	0.027	0.131
Handymax								
	ΔTAH_t	ΔFHH_t	ΔTPH_t	ΔBHH_t	ΔTAH_t	ΔFHH_t	ΔTPH_t	ΔBHH_t
$\bar{R}^2$	0.180	0.240	0.137	0.121	0.358	0.439	0.469	0.459
AIC	-0.112	-0.216	-0.195	-0.173	-0.345	-0.507	-0.669	-0.646
SC	0.008	-0.095	-0.074	-0.052	-0.194	-0.356	-0.518	-0.494

Notes: VAR models are estimated over the second sample period Jan 2003 to June 2009 in all three markets

Forecasting performance

These univariate and multivariate models estimated over the initial estimation period, are used to generate independent forecasts of spot rates on four routes for three types of vessels for the one-month, the two-month and the three-month ahead during both the whole estimation period and the second period. The forecasts of spot prices are generated over the forecast period; that is, from July 2009 to Dec 2010. All of these yield 18, 17 and 16 non-overlapping forecasts in all cases. ARIMAX and VARX models are used to make the prediction of prices for the one-month ahead, because forecasts of exogenous variables need to be known for longer horizons.

The forecasting performance of each model for spot prices across different forecast horizons is presented in Tables 4.41-4.43. The forecast accuracy of each model is assessed using the conventional root mean square error metric (RMSE), which attaches a higher weight to larger forecast errors; the mean absolute error (MAE), which measures the absolute deviation of the predicted value from the realized value; and Theil’s inequality coefficient (Theil’s), which takes into account the ability of each method to forecast trends and changes. The best forecasting model would be the one that produces the lowest RMSE, MAE, and Theil’s.

The results illustrate that all models perform reasonably well. During the whole estimation period, the ARIMA model presents highest values of RMSE, MAE and Theil’s among other models in all cases. The VAR model demonstrates lower values of RMSE, MAE and Theil’s than the ARIMA model in all forecasting horizons. In case of the one-month ahead forecast, the RMSE, MAE and Theil’s present the lowest values in the VARX model in all cases with the exception of the backhaul route for Panamax vessels. Overall, the VARX forecasting model outperforms all other models for the one-step ahead forecast. For the two-step and the three-step ahead forecasts, the VAR model performs better than the ARIMA model. These findings are applicable for forecasting models of the second period.

Table 4.41: The forecast performance of various models in the Capesize market

Panel A1: In-sample forecasts during the first sample period 1990.01-2009.06 for Capesize vessels																
	ARIMA				ARIMAX				VAR				VARX			
	One-step ahead				*One-step ahead*				*One-step ahead*				*One-step ahead*			
Route	N	RMSE	MAE	Theil's	N	RMSE	MAE	Theil's	N	RMSE	MAE	Theil's	N	RMSE	MAE	Theil's
Transatlantic	231	0.2120	0.1490	0.0110	231	0.2087	0.1496	0.0105	232	0.1592	0.1204	0.0080	232	0.1578	0.1208	0.0079
Fronthaul	231	0.1710	0.1190	0.0080	231	0.1680	0.1180	0.0080	232	0.1382	0.1020	0.0068	232	0.1366	0.1017	0.0067
Transpacific	231	0.2620	0.1590	0.0130	231	0.2600	0.1620	0.0130	232	0.1986	0.1370	0.0099	232	0.1994	0.1382	0.0100
Backhaul	231	0.2240	0.1470	0.0110	231	0.2233	0.1502	0.0114	232	0.1750	0.1293	0.0090	232	0.1757	0.1295	0.0090
Panel B1: Out-of-sample forecasts 2009.07-2010.12																
Route	*One-step ahead*				*One-step ahead*				*One-step ahead*				*One-step ahead*			
Transatlantic	18	0.3909	0.3134	0.0188	18	0.3816	0.3083	0.0183	18	0.2894	0.2453	0.0139	18	0.2867	0.246	0.0131
Fronthaul	18	0.3202	0.2621	0.0149	18	0.3085	0.2584	0.0143	18	0.2408	0.189	0.0112	18	0.2284	0.185	0.0102
Transpacific	18	0.5142	0.4026	0.0250	18	0.4987	0.3921	0.0242	18	0.3470	0.2777	0.0169	18	0.3431	0.2714	0.0162
Backhaul	18	0.4221	0.3734	0.0216	18	0.4159	0.3693	0.0213	18	0.3192	0.2943	0.0164	18	0.3142	0.2867	0.0161
Route	*Two-step ahead*								*Two-step ahead*							
Transatlantic	17	0.4703	0.3709	0.0225	-	-	-	-	17	0.3468	0.2829	0.0166	-	-	-	-
Fronthaul	17	0.3405	0.2580	0.0158	-	-	-	-	17	0.2569	0.2099	0.0120	-	-	-	-
Transpacific	17	0.5543	0.3739	0.0268	-	-	-	-	17	0.3952	0.3379	0.0192	-	-	-	-
Backhaul	17	0.5153	0.3760	0.0263	-	-	-	-	17	0.4114	0.3240	0.0210	-	-	-	-
Route	*Three-step ahead*								*Three-step ahead*							
Transatlantic	16	0.4121	0.3720	0.0197	-	-	-	-	16	0.3229	0.2689	0.0155	-	-	-	-
Fronthaul	16	0.2882	0.2285	0.0134	-	-	-	-	16	0.2179	0.1935	0.0101	-	-	-	-
Transpacific	16	0.5512	0.4257	0.0267	-	-	-	-	16	0.4192	0.3615	0.0204	-	-	-	-
Backhaul	16	0.5317	0.4506	0.0271	-	-	-	-	16	0.4403	0.3725	0.0225	-	-	-	-

Table 4.41: Continued

Panel A2: In-sample forecasts during the second sample period 2003.01-2009.06 for Capesize vessels																
	ARIMA				ARIMAX				VAR				VARX			
	One-step ahead				*One-step ahead*				*One-step ahead*				*One-step ahead*			
Route	N	RMSE	MAE	Theil's	N	RMSE	MAE	Theil's	N	RMSE	MAE	Theil's	N	RMSE	MAE	Theil's
Transatlantic	78	0.2889	0.2109	0.0134	78	0.2732	0.2006	0.0127	78	0.1913	0.1547	0.0089	78	0.1768	0.1477	0.0082
Fronthaul	78	0.2454	0.1795	0.0111	78	0.2271	0.1677	0.0103	78	0.1811	0.1420	0.0082	78	0.1630	0.1356	0.0074
Transpacific	78	0.3956	0.2413	0.0184	78	0.3809	0.2361	0.0177	78	0.2455	0.1850	0.0114	78	0.2283	0.1760	0.0106
Backhaul	78	0.3294	0.2299	0.0158	78	0.3223	0.2274	0.0155	78	0.1955	0.1614	0.0094	78	0.1904	0.1597	0.0091
Panel B2: Out-of-sample forecasts 2009.07-2010.12																
Route	*One-step ahead*				*One-step ahead*				*One-step ahead*				*One-step ahead*			
Transatlantic	18	0.4106	0.3199	0.0197	18	0.3596	0.296	0.0173	18	0.2688	0.23	0.0129	18	0.2509	0.2082	0.012
Fronthaul	18	0.3321	0.2706	0.0155	18	0.292	0.2518	0.0136	18	0.2251	0.1789	0.0105	18	0.2024	0.1578	0.009
Transpacific	18	0.5095	0.3990	0.0248	18	0.4626	0.3822	0.0225	18	0.3175	0.2644	0.0155	18	0.2955	0.2474	0.0144
Backhaul	18	0.4240	0.3753	0.0217	18	0.3878	0.3486	0.0199	18	0.2869	0.2337	0.0147	18	0.2746	0.2270	0.0141
Route	*Two-step ahead*								*Two-step ahead*							
Transatlantic	17	0.4496	0.3441	0.0215	-	-	-	-	17	0.3067	0.2501	0.0147		-	-	-
Fronthaul	17	0.3297	0.2517	0.0153	-	-	-	-	17	0.2267	0.1860	0.0106		-	-	-
Transpacific	17	0.5412	0.3576	0.0262	-	-	-	-	17	0.3664	0.3059	0.0178		-	-	-
Backhaul	17	0.5253	0.3859	0.0268	-	-	-	-	17	0.3911	0.3229	0.0200		-	-	-
Route	*Three-step ahead*								*Three-step ahead*							
Transatlantic	16	0.3692	0.3375	0.0177	-	-	-	-	16	0.2826	0.2237	0.0136		-	-	-
Fronthaul	16	0.2656	0.2210	0.0123	-	-	-	-	16	0.1862	0.1618	0.0087		-	-	-
Transpacific	16	0.5374	0.4144	0.0260	-	-	-	-	16	0.3710	0.3298	0.0181		-	-	-
Backhaul	16	0.5430	0.4590	0.0277	-	-	-	-	16	0.4183	0.3614	0.0214		-	-	-

Notes: RMSE is the conventional root mean square error metric; MAE denotes mean absolute error and Theil's is the Theil's inequality coefficient

Table 4.42: The forecast performance of various models in the Panamax market

Panel A1: In-sample forecasts during the first sample period 1990.01-2009.06 for Panamax vessels																
	ARIMA				ARIMAX				VAR				VARX			
	One-step ahead				*One-step ahead*				*One-step ahead*				*One-step ahead*			
Route	N	RMSE	MAE	Theil's	N	RMSE	MAE	Theil's	N	RMSE	MAE	Theil's	N	RMSE	MAE	Theil's
Transatlantic	232	0.1911	0.1306	0.0101	232	0.1863	0.1270	0.0098	232	0.1452	0.1100	0.0076	232	0.1466	0.1106	0.0077
Fronthaul	232	0.1630	0.1171	0.0084	232	0.1596	0.1140	0.0082	232	0.1248	0.0978	0.0064	232	0.1283	0.1001	0.0066
Transpacific	232	0.2080	0.1391	0.0110	232	0.2062	0.1398	0.0109	232	0.1587	0.1154	0.0084	232	0.1637	0.1180	0.0087
Backhaul	232	0.2202	0.1427	0.0119	232	0.2180	0.1429	0.0117	232	0.1739	0.1222	0.0094	232	0.1784	0.1228	0.0096
Panel B1: Out-of-sample forecasts 2009.07-2010.12																
Route	*One-step ahead*				*One-step ahead*				*One-step ahead*				*One-step ahead*			
Transatlantic	18	0.2998	0.2544	0.0147	18	0.2858	0.2367	0.014	18	0.2374	0.1897	0.0116	18	0.2342	0.1827	0.0115
Fronthaul	18	0.1892	0.1537	0.009	18	0.1793	0.1468	0.0085	18	0.1732	0.1258	0.0083	18	0.1682	0.1217	0.0080
Transpacific	18	0.2350	0.1991	0.0117	18	0.2264	0.1921	0.0113	18	0.2053	0.1540	0.0102	18	0.2029	0.1551	0.0103
Backhaul	18	0.2094	0.1591	0.0110	18	0.2019	0.1542	0.0106	18	0.1645	0.1182	0.0086	18	0.1662	0.1158	0.0087
Route	*Two-step ahead*								*Two-step ahead*							
Transatlantic	17	0.3245	0.2525	0.0158		-	-	-	17	0.2604	0.2157	0.0127	-	-	-	-
Fronthaul	17	0.2070	0.1639	0.0098		-	-	-	17	0.1701	0.1298	0.0081	-	-	-	-
Transpacific	17	0.3004	0.2420	0.0149		-	-	-	17	0.2466	0.2019	0.0122	-	-	-	-
Backhaul	17	0.2728	0.2030	0.0142		-	-	-	17	0.1641	0.1295	0.0086	-	-	-	-
Route	*Three-step ahead*								*Three-step ahead*							
Transatlantic	16	0.3504	0.3120	0.0170		-	-	-	16	0.2765	0.2151	0.0134	-	-	-	-
Fronthaul	16	0.2363	0.2061	0.0112		-	-	-	16	0.2046	0.1659	0.0097	-	-	-	-
Transpacific	16	0.3456	0.3056	0.0171		-	-	-	16	0.2855	0.2380	0.0141	-	-	-	-
Backhaul	16	0.3245	0.2898	0.0169		-	-	-	16	0.2195	0.1983	0.0114	-	-	-	-

Table 4.42: Continued

Panel A2: In-sample forecasts during the second sample period 2003.01-2009.06 for Panamax vessels																
	ARIMA				ARIMAX				VAR				VARX			
	One-step ahead				*One-step ahead*				*One-step ahead*				*One-step ahead*			
Route	N	RMSE	MAE	Theil's	N	RMSE	MAE	Theil's	N	RMSE	MAE	Theil's	N	RMSE	MAE	Theil's
Transatlantic	78	0.2642	0.1731	0.0129	78	0.2508	0.1650	0.0122	78	0.1764	0.1304	0.0086	78	0.1649	0.1248	0.0080
Fronthaul	78	0.2108	0.1475	0.0101	78	0.1974	0.1376	0.0095	78	0.1402	0.1108	0.0067	78	0.1312	0.1057	0.0063
Transpacific	78	0.2961	0.1934	0.0145	78	0.2910	0.1986	0.0143	78	0.2135	0.1556	0.0105	78	0.2139	0.1563	0.0105
Backhaul	78	0.3063	0.2008	0.0152	78	0.3023	0.2035	0.0150	78	0.2248	0.1577	0.0112	78	0.2259	0.1618	0.0112
Panel B2: Out-of-sample forecasts 2009.07-2010.12																
Route	*One-step ahead*				*One-step ahead*				*One-step ahead*				*One-step ahead*			
Transatlantic	18	0.3113	0.2664	0.0153	18	0.2846	0.2391	0.0140	18	0.2470	0.1900	0.0121	18	0.2252	0.1632	0.0111
Fronthaul	18	0.2018	0.1650	0.0096	18	0.1894	0.1504	0.0090	18	0.1976	0.1512	0.0094	18	0.1678	0.1149	0.0080
Transpacific	18	0.2382	0.2042	0.0119	18	0.2267	0.1919	0.0113	18	0.2147	0.1643	0.0107	18	0.1977	0.1511	0.0099
Backhaul	18	0.2110	0.1645	0.0111	18	0.2013	0.1566	0.0106	18	0.1804	0.1307	0.0095	18	0.1648	0.1189	0.0087
Route	*Two-step ahead*								*Two-step ahead*							
Transatlantic	17	0.3268	0.2569	0.0159		-	-	-	17	0.2402	0.1933	0.0117		-	-	-
Fronthaul	17	0.2105	0.1728	0.0100		-	-	-	17	0.1766	0.1389	0.0084		-	-	-
Transpacific	17	0.2988	0.2420	0.0148		-	-	-	17	0.2485	0.1995	0.0123		-	-	-
Backhaul	17	0.2679	0.2021	0.0140		-	-	-	17	0.1735	0.1419	0.0091		-	-	-
Route	*Three-step ahead*								*Three-step ahead*							
Transatlantic	16	0.3502	0.3073	0.0170		-	-	-	16	0.2576	0.2081	0.0125		-	-	-
Fronthaul	16	0.2350	0.2016	0.0111		-	-	-	16	0.1977	0.1662	0.0094		-	-	-
Transpacific	16	0.3421	0.3014	0.0169		-	-	-	16	0.2875	0.2411	0.0142		-	-	-
Backhaul	16	0.3160	0.2836	0.0164		-	-	-	16	0.2324	0.2137	0.0121		-	-	-

Notes: RMSE is the conventional root mean square error metric; MAE denotes mean absolute error and Theil's is the Theil's inequality coefficient

Table 4.43: The forecast performance of various models in the Handymax market

Panel A1: In-sample forecasts during the first sample period 1990.01-2009.06 for Handymax vessels																
	ARIMA				ARIMAX				VAR				VARX			
	One-step ahead				*One-step ahead*				*One-step ahead*				*One-step ahead*			
Route	N	RMSE	MAE	Theil's	N	RMSE	MAE	Theil's	N	RMSE	MAE	Theil's	N	RMSE	MAE	Theil's
Transatlantic	232	0.1429	0.0870	0.0076	232	0.1403	0.0857	0.0075	232	0.1252	0.0768	0.0067	232	0.1228	0.0767	0.0065
Fronthaul	232	0.1372	0.0801	0.0071	232	0.1358	0.0789	0.0071	232	0.1169	0.0688	0.0061	232	0.1158	0.0690	0.0060
Transpacific	232	0.1380	0.0842	0.0074	232	0.1369	0.0851	0.0073	232	0.1129	0.0721	0.0060	232	0.1116	0.0719	0.0060
Backhaul	232	0.1489	0.0914	0.0081	232	0.1474	0.0927	0.0080	232	0.1246	0.0804	0.0068	232	0.1232	0.0810	0.0067
Panel B1: Out-of-sample forecasts 2009.07-2010.12																
Route	*One-step ahead*				*One-step ahead*				*One-step ahead*				*One-step ahead*			
Transatlantic	18	0.2219	0.1895	0.0112	18	0.2162	0.1885	0.0109	18	0.2079	0.1818	0.0105	18	0.2016	0.1786	0.0102
Fronthaul	18	0.1479	0.1231	0.0072	18	0.1461	0.1188	0.0071	18	0.1468	0.1304	0.0072	18	0.1426	0.1282	0.0070
Transpacific	18	0.1792	0.1428	0.0092	18	0.1780	0.1380	0.0092	18	0.1517	0.1268	0.0078	18	0.1484	0.1236	0.0076
Backhaul	18	0.1706	0.1284	0.0093	18	0.1691	0.1267	0.0092	18	0.1430	0.1065	0.0078	18	0.1416	0.1111	0.0077
Route	*Two-step ahead*								*Two-step ahead*							
Transatlantic	17	0.2473	0.1656	0.0124	-	-	-	-	17	0.2272	0.1556	0.0113	-	-	-	-
Fronthaul	17	0.1820	0.1198	0.0088	-	-	-	-	17	0.1599	0.1186	0.0078	-	-	-	-
Transpacific	17	0.1966	0.1667	0.0101	-	-	-	-	17	0.1665	0.1388	0.0085	-	-	-	-
Backhaul	17	0.2144	0.1718	0.0116	-	-	-	-	17	0.1676	0.1371	0.0091	-	-	-	-
Route	*Three-step ahead*								*Three-step ahead*							
Transatlantic	16	0.2925	0.2594	0.0146	-	-	-	-	16	0.2910	0.2607	0.0145	-	-	-	-
Fronthaul	16	0.1986	0.1503	0.0096	-	-	-	-	16	0.1967	0.1683	0.0095	-	-	-	-
Transpacific	16	0.2390	0.2009	0.0122	-	-	-	-	16	0.2324	0.2033	0.0119	-	-	-	-
Backhaul	16	0.2607	0.2281	0.0141	-	-	-	-	16	0.2331	0.1992	0.0126	-	-	-	-

Table 4.43: Continued

Panel A2: In-sample forecasts during the second sample period 2003.01-2009.06 for Handymax vessels																
	ARIMA				ARIMAX				VAR				VARX			
	One-step ahead				*One-step ahead*				*One-step ahead*				*One-step ahead*			
Route	N	RMSE	MAE	Theil's	N	RMSE	MAE	Theil's	N	RMSE	MAE	Theil's	N	RMSE	MAE	Theil's
Transatlantic	78	0.2286	0.1552	0.0113	78	0.2136	0.1370	0.0106	78	0.1910	0.1218	0.0095	78	0.1774	0.1149	0.0088
Fronthaul	78	0.2169	0.1342	0.0106	78	0.2095	0.1269	0.0103	78	0.1761	0.1045	0.0086	78	0.1681	0.1012	0.0082
Transpacific	78	0.2099	0.1442	0.0105	78	0.2066	0.1461	0.0104	78	0.1624	0.1104	0.0082	78	0.1546	0.1110	0.0078
Backhaul	78	0.2117	0.1397	0.0108	78	0.2079	0.1394	0.0106	78	0.1643	0.1079	0.0084	78	0.1578	0.1069	0.0080
Panel B2: Out-of-sample forecasts 2009.07-2010.12																
Route	*One-step ahead*				*One-step ahead*				*One-step ahead*				*One-step ahead*			
Transatlantic	18	0.2222	0.1896	0.0112	18	0.2102	0.1785	0.0106	18	0.2164	0.1887	0.0109	18	0.1929	0.1683	0.0097
Fronthaul	18	0.1482	0.1234	0.0072	18	0.1440	0.1199	0.0070	18	0.1554	0.1359	0.0076	18	0.1368	0.1253	0.0067
Transpacific	18	0.1817	0.1444	0.0094	18	0.1795	0.1346	0.0092	18	0.1443	0.1216	0.0074	18	0.1354	0.1028	0.0070
Backhaul	18	0.1742	0.1309	0.0095	18	0.1718	0.1302	0.0093	18	0.1414	0.1069	0.0077	18	0.1435	0.1201	0.0078
Route	*Two-step ahead*								*Two-step ahead*							
Transatlantic	17	0.2472	0.1653	0.0124	-	-	-	-	17	0.2258	0.1642	0.0113	-	-	-	-
Fronthaul	17	0.1818	0.1196	0.0088	-	-	-	-	17	0.1571	0.1200	0.0076	-	-	-	-
Transpacific	17	0.1969	0.1672	0.0101	-	-	-	-	17	0.1535	0.1260	0.0079	-	-	-	-
Backhaul	17	0.2132	0.1727	0.0116	-	-	-	-	17	0.1689	0.1429	0.0092	-	-	-	-
Route	*Three-step ahead*								*Three-step ahead*							
Transatlantic	16	0.2924	0.2594	0.0146	-	-	-	-	16	0.2931	0.2689	0.0146	-	-	-	-
Fronthaul	16	0.1984	0.1502	0.0096	-	-	-	-	16	0.2016	0.1775	0.0098	-	-	-	-
Transpacific	16	0.2391	0.1987	0.0122	-	-	-	-	16	0.2104	0.1696	0.0108	-	-	-	-
Backhaul	16	0.2581	0.2271	0.0140	-	-	-	-	16	0.2431	0.2003	0.0132	-	-	-	-

Notes: RMSE is the conventional root mean square error metric; MAE denotes mean absolute error and Theil's is the Theil's inequality coefficient

However, compared to the forecast performance of models during the whole estimation period, the forecast performance of models estimated during the second period exhibits mixed results.

For the one-step ahead forecast, the VARX model in the second period gives the lowest values of RMSE, MAE and Theil's in all cases with the exception of the backhaul route for Handymax vessels.

For the two-step ahead forecast, the VAR model estimated during the second period outperforms that during the whole period in all three markets. Exceptions are the backhaul route for Panamax and Handymax vessels.

For the three-step ahead forecast, the VAR model in the second period gives better forecasting performance for Capesize vessels. For Panamax vessels, the VAR model in the second period outperforms that in the whole period on the transatlantic and the fronthaul routes, while on the transpacific and the backhaul routes, the VAR model in the second period performs worse. For Handymax vessels, the VAR model in the second period performs better on the transpacific route than that in the whole period, while on the rest routes, the VAR model in the whole period has the better forecast performance.

The finding that the ARIMA model is the least accurate has two implications. Firstly, the forecasting accuracy can be improved by using interrelationships between spot rates on all routes rather than simply using information contained in the univariate spot series alone. Secondly, the forecast accuracy can be further improved by making use of exogenous variables influencing spot prices, rather than using an ARIMA or a VAR model. It is worth noting that the shifting market situations may change relations between prices on four routes, and have an impact on the short-term prediction. Therefore, it seems that the VARX model in the second period provides superior forecasts for one-month ahead, compared to the other forecasting models.

4.5.2. The forecasting performance of FFA prices

The forecasting ability of the futures or forward prices has always been the interesting subject and attracted much attention of researchers. Previous research on the forecasting capabilities of futures or forward prices can be seen in Kavussanos and Nomikos (1999, 2000, 2003) and Batchelor, Alizadeh and Visvikis (2007) among others. One conclusion may be drawn from these studies that futures or forward prices contain useful future information of spot ones.

The unbiasedness hypothesis of the freight forward prices and interrelationships between FFA prices and spot ones were investigated in Section 4.4. It is found that the hypothesis cannot be rejected at the conventional significance levels and FFA prices provide useful information about future movement of the spot market. Based on the findings of Section 4.4, the forecasting capacities of FFA prices for predicting monthly time charter average and daily prices in the spot market are investigated in this section.

4.5.2.1. The forecasting capability of FFA prices for monthly spot time charter average

The FFA price n months from maturity provides a forecast of the underlying settlement price on the maturity day. Because the settlement price of the forward contract is calculated as the average price of the last seven trading days of the contract on routes C4, C7, P2A and P3A, the forecasts should be obtained for these particular days and this requires that forecasting models should be estimated using daily data. While for the time charter average in each market, FFA prices of the average time charter rates provide forecasts of the underlying monthly spot prices. The forecasting performance of FFA prices of TCC, TCP and TCH one month prior to maturity is investigated in this section, because only FFA prices of the TC average with one month maturity are available from Baltic Exchange since Sept 2005. This is done by comparing the forecasting accuracy of freight forward prices one month before maturity to the accuracy of forecasts generated by various time-series models.

The indicator of one-month index change is incorporated into the VAR model for each ship size. The

US Dollar Index is employed into forecasting models as the exogenous variable. The time-series models used are ARMA, ARMAX, VAR, and VARX models. The estimation period of forecasting models runs from Sept 2005 to Jun 2009, and the period of July 2009 to Dec 2010 is utilized for the prediction. Because coefficients of the error correction term of spot prices are insignificant for the Capesize and the Panamax, and error correction coefficients of both spot and forward prices are significantly positive for the Handymax, the VECM model is therefore not included for the investigation.

The estimates of various forecasting models for Capesize, Panamax and Handymax vessels are shown in Tables 4.44-4.46, and forecasts by various models are presented in Table 4.47. Results indicate that forward prices seem to outperform all the time series models for the one-month ahead forecasts for three types of vessels, and these results are consistent with findings in Section 4.4 that the unbiasedness hypothesis holds at the conventional significance levels and forward prices seem to be the best forecasts of spot rates. The conclusion, however, should be drawn very carefully, because the estimation period in this research is very short due to the data availability. Further research ought to be made when more figures are included.

Overall the results indicate that forward prices contain valuable information regarding future spot rates. The forecasts implied by forward prices are found to perform well compared to more complex time-series models. These price discovery properties of forward prices imply that market participants may use dry bulk freight forward prices to guide decisions in the physical market, and forward prices can thereby contribute to a more efficient allocation of economic resources.

Table 4.44: Estimates of forecasting models for Capesize vessels during the period Sept 2005 to Jun 2009

	ARMA		ARMAX		VAR			VARX		
	$\Delta TCCS_t$	$\Delta TCCF_t$	$\Delta TCCS_t$	$\Delta TCCF_t$	$\Delta TCCS_t$	$\Delta TCCF_t$	ΔBCI_t	$\Delta TCCS_t$	$\Delta TCCF_t$	ΔBCI_t
$\Delta TCCS_{t-1}$	0.652** (2.609)		0.435* (1.951)		-0.795** (-2.58)	0.233* (1.557)	-0.516 (-1.379)	-1.006** (-3.464)	0.104 (0.726)	-0.599 (-1.612)
$\Delta TCCS_{t-2}$	-0.426** (-3.010)		-0.377** (-2.962)							
$\Delta TCCF_{t-1}$		0.754** (3.166)		0.572** (3.241)	0.151 (0.761)	-0.143 (-1.484)	-0.040 (-0.167)	0.382* (1.818)	0.003 (0.028)	0.037 (0.137)
$\Delta TCCF_{t-2}$		-0.581** (-3.184)		-0.526** (-3.294)						
ΔBCI_{t-1}					1.692** (6.924)	1.101** (9.262)	0.959** (3.235)	1.654** (7.222)	1.116** (9.875)	0.824** (2.811)
$\Delta USDX_{t-1}$			-7.560** (-3.147)	-5.879** (02.284)				-7.271** (-3.593)	-3.289** (3.201)	-6.463** (-2.496)
$\overline{R}^2$	0.343	0.434	0.442	0.515	0.695	0.932	0.290	0.759	0.945	0.376
AIC	0.736	0.763	0.569	0.628	0.056	-1.385	0.443	-0.139	-1.551	0.354
SC	0.811	0.845	0.683	0.792	0.178	-1.263	0.565	0.063	-1.348	0.557
$Q(12)$	9.888 [0.450]	9.227 [0.511]	6.109 [0.91]	5.881 [0.922]	7.349 [0.834]	15.245 [0.228]	14.646 [0.26]	9.681 [0.644]	23.37 [0.025]	14.215 [0.287]
$Q^2(12)$	41.513 [0.00]	25.981 [0.00]	28.09 [0.00]	23.271 [0.04]	36.453 [0.00]	17.08 [0.15]	28.432 [0.00]	16.957 [0.15]	17.376 [0.13]	22.236 [0.03]

Notes:

- ♦ All the series are measured in logarithmic first differences. $\Delta TCCS_t$ and $\Delta TCCF_t$ mean logarithmic first differences of time charter rates for the Capesize in the spot market, and of FFA prices one month prior to maturity in the forward market.
- ♦ ΔBCI_t means the monthly change of Baltic Capesize Index.

Table 4.45: Estimates of forecasting models for Panamax vessels during the period Jan 2005 to Jun 2009

	ARMA		ARMAX		VAR			VARX		
	$\Delta TCPS_t$	$\Delta TCPF_t$	$\Delta TCPS_t$	$\Delta TCPF_t$	$\Delta TCPS_t$	$\Delta TCPF_t$	ΔBPI_t	$\Delta TCPS_t$	$\Delta TCPF_t$	ΔBPI_t
$\Delta TCPS_{t-1}$	0.433** (3.392)		0.279* (1.904)		-1.188** (-6.274)	-0.217** (-2.034)	-1.216** (-3.711)	-1.198** (6.476)	-0.148* (-1.706)	-1.09** (-3.369)
$\Delta TCPF_{t-1}$		0.459** (3.207)		0.309** (2.120)	0.651** (4.817)	0.105 (1.572)	0.553** (2.364)	0.589** (4.068)	0.067 (1.033)	0.409* (1.716)
ΔBPI_{t-1}					1.367** (10.552)	1.046** (16.392)	1.109** (4.945)	1.368** (10.481)	0.987** (16.18)	0.969** (4.227)
$\Delta USDX_{t-1}$			-4.102** (-2.305)	-4.924** (-2.647)				-1.428* (1.739)	-1.887** (-3.307)	-3.720* (-1.946)
$\overline{R}^2$	0.183	0.191	0.267	0.312	0.780	0.945	0.382	0.778	0.952	0.380
AIC	0.211	0.249	0.149	0.140	-0.930	-2.347	0.167	-0.956	-2.503	0.122
SC	0.249	0.289	0.224	0.221	-0.809	-2.225	0.289	-0.794	-2.300	0.284
$Q(12)$	8.674 [0.730]	11.262 [0.507]	12.102 [0.437]	10.35 [0.586]	14.73 [0.256]	15.296 [0.226]	22.253 [0.035]	11.764 [0.465]	14.273 [0.284]	13.96 [0.30]
$Q^2(12)$	11.508 [0.487]	17.005 [0.149]	12.46 [0.409]	18.79 [0.10]	11.96 [0.449]	11.778 [0.464]	7.07 [0.853]	7.985 [0.786]	5.047 [0.956]	10.79 [0.628]

Notes:

- ♦ All the series are measured in logarithmic first differences. $\Delta TCPS_t$ and $\Delta TCPF_t$ mean logarithmic first differences of time charter rates for the Panamax in the spot market, and of FFA prices one month prior to maturity in the forward market.
- ♦ ΔBPI_t means monthly change of Baltic Panamax index.

Table 4.46: Estimates of forecasting models for Handymax vessels during the period Jan 2005 to Jun 2009

	ARMA		ARMAX		VAR			VARX		
	$\Delta TCHS_t$	$\Delta TCHF_t$	$\Delta TCHS_t$	$\Delta TCHF_t$	$\Delta TCHS_t$	$\Delta TCHF_t$	$\Delta BHMI_t$	$\Delta TCHS_t$	$\Delta TCHF_t$	$\Delta BHMI_t$
$\Delta TCHS_{t-1}$	0.434** (3.443)		0.351** (2.628)		-0.752** (-2.172)	-0.007 (-0.038)	-0.316 (-0.492)	-0.711** (-2.094)	0.034 (0.222)	-0.233 (-0.373)
$\Delta TCHF_{t-1}$		0.368** (2.546)		0.258 (1.664)	0.488* (1.881)	0.050 (0.382)	0.344 (0.717)	0.389 (1.498)	-0.047 (-0.397)	0.149 (0.312)
$\Delta BHMI_{t-1}$					0.900** (5.554)	0.780** (9.528)	0.206 (0.686)	0.870** (5.457)	0.751** (10.427)	0.146 (0.498)
$\Delta USDX_{t-1}$			-2.633* (-1.678)	-3.262* (-1.753)				-2.230* (-1.70)	-2.193** (-3.704)	-4.418* (-1.829)
$\overline{R}^2$	0.188	0.131	0.215	0.171	0.559	0.891	0.018	0.579	0.917	0.037
AIC	-0.075	0.148	-0.092	0.123	-0.524	-1.888	0.709	-0.548	-2.138	0.674
SC	-0.038	0.189	-0.017	0.204	-0.402	-1.767	0.831	-0.386	-1.976	0.836
$Q(12)$	9.884 [0.626]	9.919 [0.623]	13.22 [0.353]	13.62 [0.326]	13.99 [0.301]	20.84 [0.053]	13.983 [0.87]	15.52 [0.214]	10.72 [0.553]	14.79 [0.253]
$Q^2(12)$	10.28 [0.671]	14.142 [0.292]	8.424 [0.751]	19.242 [0.115]	10.57 [0.566]	14.29 [0.28]	141.08 [0.00]	9.792 [0.634]	9.969 [0.685]	8.578 [0.738]

Notes:

- ♦ All the series are measured in logarithmic first differences. $\Delta TCHS_t$ and $\Delta TCHF_t$ the mean logarithmic first differences of time charter rates for the Handymax in the spot market, and of FFA prices one month prior to maturity in the forward market.
- ♦ $\Delta BHMI_t$ means the monthly change of Baltic Handymax Index

Table 4.47: The forecasting performance of various models for the spot time charter rates in the dry bulk market

	TCC				TCP				TCH			
	One-step ahead				*One-step ahead*				*One-step ahead*			
Models	N	RMSE	MAE	Theil's	N	RMSE	MAE	Theil's	N	RMSE	MAE	Theil's
ARMA	18	0.4313	0.3527	0.0204	18	0.2181	0.1873	0.0108	18	0.1509	0.1282	0.0076
ARMAX	18	0.3942	0.3149	0.0187	18	0.1959	0.1675	0.0097	18	0.1407	0.1155	0.0070
VAR	18	0.3072	0.2568	0.0146	18	0.1346	0.1093	0.0067	18	0.1208	0.1022	0.0060
VARX	18	0.2725	0.2362	0.0130	18	0.1298	0.1056	0.0064	18	0.1113	0.0980	0.0056
FFA prices	18	0.2286	0.1893	0.0109	18	0.1264	0.1130	0.0063	18	0.1064	0.0907	0.0053

Notes: RMSE is the conventional root mean square error metric; MAE denotes mean absolute error and Theil's is the Theil's inequality coefficient.

4.5.2.2. The forecasting capability of FFA prices for daily spot rates

As proven in Section 4.4, there exists a two-way feed back causal relationship between daily forward prices and daily spot ones, indicating that the predictability of spot returns and forward returns may be improved by incorporating information of forward prices and spot prices, respectively. The forecasting performance of daily FFA prices on daily spot rates is investigated here.

As discussed in sub-section 4.4.2, there exist several structural breaks during the period of 4th Jan 2005 to 24th Dec 2010 (2005:0104-2008:0829; 2008:0901-2009:0130; 2009:0202-2010:1224). Various forecasting models are estimated in this part during the period of 2nd Feb 2009 to 28th May 2010, and the independent out-of-sample N-period ahead forecasts are generated over the forecast period from 1st June 2010 to 24th Dec 2010 at the C4, C7, P2A and P3A routes. During the estimation period of 2009:0202-2010:0528, all the daily spot and forward prices are observed to be statistically non-stationary in logarithmic levels, but stationary in logarithmic first differences at the conventional significance levels, shown in Table 4.48. Cointegration tests in Table 4.49 reveal that during the estimation period, daily spot prices and the adjusted forward prices are cointegrated at the 5% significance level at the routes of C4, C7 and P3A, while there is no significant cointegration relationship between daily spot and forward prices at the route of P2A.

To perform a comprehensive comparison of the forecasting performance, we consider four alternative models of predicting daily spot prices and daily forward prices, respectively, including a VEC model, measuring both short-term dynamics and long-run relationship between variables; a VAR model in first differences without the error-correction terms, employed here as a benchmark for the contribution of the ECT in the forecasting accuracy; a ARIMA (Box-Jenkins, 1970) models; and a simple random walk model (the RW model afterwards), considered for the benchmark comparison.

The estimates of various forecasting models for daily spot and forward returns, selected using the SBIC and ensuring well specified diagnostics, are presented in Tables 4.50-4.51. These forecasting models are estimated during the estimation period of 2009:0202-2010:0528 to obtain the out-of-sample forecasts for multiple steps ahead (up to 20 steps). In order to avoid the bias induced by serially correlated overlapping forecast errors, we recursively augment our estimation period by N-periods ahead every time.

The forecast performance statistics, measured by the root mean square errors (RMSE) for each model, across different forecast horizons, are presented in Tables 4.52-4.55 for spot prices and forward prices, respectively. Since no cointegrating relationship exists between spot and forward prices on the route P2A, the VECM is not employed on that route to make the prediction. The RMSE measures differ by small margins across models. These differences may reflect the relative adequacy of the models under comparisons, but they may also result from small-sample properties.

Table 4.48: Descriptive statistics of logarithmic first differences of daily spot prices and daily one-month FFA prices during the estimation period of 2009:0202-2010:0528

Routes	N	Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	ADF(lags) Level	ADF(lags) 1st diff	PP(lags) Level	PP (lags) 1st diff
ΔC4S	331	0.002	0.035	1.661	11.438	1134 [0.00]	-2.26(2)	-9.69(1)	-2.27(7)	-8.53(13)
ΔC4F	331	0.001	0.027	2.897	27.754	8913 0.00]	-2.02(1)	-11.07(0)	-1.94(7)	-11.08(4)
ΔC7S	331	0.003	0.034	0.858	5.012	96[0.00]	-2.26(2)	-8.88(1)	-2.11(8)	-7.63(22)
ΔC7F	331	0.002	0.025	3.488	31.984	12256[0.00]	-2.12(2)	-7.59(1)	-2.05(9)	-9.77(1)
ΔP2AS	331	0.0014	0.026	-0.103	5.671	91 [0.00]	-2.73(2)	-8.39(1)	-2.86(7)	-5.56(22)
ΔP2AF	331	0.0013	0.028	0.762	5.581	95 [0.00]	-2.75(1)	-10.03(0)	-2.71(4)	-10.06(5)
ΔP3AS	331	0.0015	0.044	1.046	7.997	360[0.00]	-3.00(2)	-8.25(1)	-2.87(7)	-5.15(20)
ΔP3AF	331	0.0015	0.036	1.245	9.810	633[0.00]	-2.88(1)	-9.06(0)	-2.82(6)	-8.29(11)

Notes:

- N is the number of observations.
- Figures in square brackets [·] indicate exact significance levels
- Skew and Kurt are the estimated centralized third and fourth moments of the data; their symptotic distributions under the null are $T\hat{\alpha}_3'\hat{\alpha}_3/6 \sim \chi^2(1)$ and $T(\hat{\alpha}_4-3)'(\hat{\alpha}_4-3)/24 \sim \chi^2(1)$ respectively
- J-B is the Jarque-Bera (1980) test for normality, distributed as $\chi^2(2)$
- ADF is the Augmented Dickey and Fuller (1981) test. The ADF regressions include none of intercept and trend terms. The lag length of the ADF test (in parentheses) is determined by minimizing the SBIC. PP is the Philips and Perron(1988) test; the truncation lag for the test is in parentheses. The 5% critical values for the ADF and PP tests during the first, the second and the third sub-period are -2.864, -2.889 and -2.867, respectively.
- Lev and 1st diffs refer to price series in log-levels and log-first differences, respectively.

Table 4.49: Johansen (1988) tests for the number of cointegrating vectors between daily spot and FFA prices druing the estimation period of 2009:0202-2010:0528

	Lags	Hypothesis (maximal)		Test statistic	Hypothesis (trace)		Test Statistic	95% Critical values		Cointegrating vector
		H_0	H_1	$\lambda_{\max}$	H_0	H_1	λ_{trace}	$\lambda_{\max}$	λ_{trace}	$\beta' = (1, \beta_1, \beta_2)$
C4	2	$r=0$	$r=1$	19.56	$r=0$	$r=1$	26.23	15.89	20.26	(1,0.564,-1.239)
		$r\le 1$	$r=2$	6.67	$r\le 1$	$r=2$	6.67	9.16	9.16	
C7	3	$r=0$	$r=1$	16.89	$r=0$	$r=1$	23.26	15.89	20.26	(1,0.55,-1.218)
		$r\le 1$	$r=2$	6.37	$r\le 1$	$r=2$	6.37	9.16	9.16	
P2A	2	$r=0$	$r=1$	12.24	$r=0$	$r=1$	20.81	15.89	20.26	-
		$r\le 1$	$r=2$	8.58	$r\le 1$	$r=2$	8.58	9.16	9.16	
P3A	2	$r=0$	$r=1$	25.67	$r=0$	$r=1$	26.29	12.32	20.26	(1,0,-1.004)
		$r\le 1$	$r=2$	0.62	$r\le 1$	$r=2$	0.62	4.12	9.16	

Notes:

- Lags is the lag length of a VAR model; the lag length is determined using the SBIC(1978), AIC(1973) and LR tests. r represents the number of cointegrating vectors
- $\lambda_{\max}(r, r+1) = -T\ln(1-\hat{\lambda}_{r+1})$ and $\lambda_{trace}(r) = -T\sum_{i=r+1}^{n}\ln(1-\hat{\lambda}_i)$ where $\hat{\lambda}_i$ are the estimated eigenvalues of the $\prod$ matrix in Eq.(1).

Table 4.50: The estimates of the forecasting models for Capesize vessels during the sample period of 2009.2.1-2010.5.30

	C4						C7					
Regressors	ARMA		VAR		VECM		ARMA		VAR		VECM	
	ΔS_t	ΔF_t	ΔS_t	ΔF_t	ΔS_t	ΔF_t	ΔS_t	ΔF_t	ΔS_t	ΔF_t	ΔS_t	ΔF_t
$\alpha_{s,f}$					-0.042* (-1.867)	0.049** (2.244)					0.001 (0.068)	0.053** (3.404)
ΔS_{t-1}	0.737** (13.634)		0.411** (6.40)	0.117* (1.856)	0.422** (6.569)	0.104* (1.655)	0.800** (14.634)		0.562** (8.26)	-0.017 (-0.264)	0.555** (8.247)	-0.016 (-0.253)
ΔS_{t-2}	-0.194** (-3.598)		-0.232** (-4.165)	-0.053 (-0.973)	-0.206** (-3.586)	-0.085 (-1.507)	-0.072** (-1.025)		-0.097 (-1.271)	0.159** (2.256)	-0.093 (-1.239)	0.119* (1.705)
ΔS_{t-3}							-0.138** (-2.517)		-0.153** (-2.462)	-0.034 (-0.588)	-1.663** (-2.646)	-0.076 (-1.298)
ΔF_{t-1}		0.458** (9.382)	0.489** (7.289)	0.374** (5.672)	0.466** (6.857)	0.401** (6.019)		0.494** (8.957)	0.336** (4.518)	0.503** (7.308)	0.466** (6.857)	0.481** (7.191)
ΔF_{t-2}			0.186** (2.562)	0.022 (0.301)	0.163** (2.223)	0.049 (0.683)		0.174** (2.863)	0.257** (3.343)	0.077 (1.082)	0.163** (2.223)	0.109 (1.589)
ΔF_{t-3}								-0.104* (-1.887)	-0.079 (-1.045)	-0.145** (-2.077)	-0.056 (-0.786)	-0.124* (-1.818)
$\overline{R}^2$	0.402	0.208	0.496	0.211	0.499	0.221	0.505	0.310	0.562	0.319	0.563	0.325
AIC	-4.375	-4.582	-4.543	-4.576	-4.547	-4.586	-4.616	-4.881	-4.731	-4.885	-4.728	-4.873
SC	-4.352	-4.570	-4.497	-4.530	-4.490	-4.528	-4.582	-4.847	-4.662	-4.816	-4.648	-4.792
$Q(20)$	23.096 [0.187]	19.78 [0.408]	28.30 [0.132]	20.49 [0.49]	30.39 [0.084]	17.64 [0.611]	27.03 [0.058]	30.41 [0.06]	12.98 [0.87]	30.39 [0.064]	13.47 [0.856]	26.79 [0.141]
$Q^2(20)$	30.607 [0.032]	8.428 [0.982]	24.10 [0.238]	8.44 [0.98]	21.483 [0.369]	8.57 [0.987]	81.40 [0.00]	10.02 [0.90]	59.88 [0.00]	11.43 [0.93]	60.56 [0.00]	6.46 [0.99]

Notes:

- All series are measured in logarithmic first differences. Δ means the first difference. S_t denotes the spot rates at time t, F_t refers to the forward price with the perpetual maturity.
- * and ** denote significance at the 5% and 10% levels, respectively.
- Figures in parentheses (.) and in squared brackets [.] indicate *t*-statistics and exact significance levels, respectively.
- $Q(20)$ and $Q^2(20)$ are the Ljung-Box (1978) tests for 20th order serial correlation and heteroskedasticity in the residuals and in the squared residuals, respectively.

Table 4.51: The estimates of the forecasting models for Panamax vessels during the sample period of 2009.2.1-2010.5.30

Regressor	P2A				P3A					
	ARMA		VAR		ARMA		VAR		VECM	
	ΔS_t	ΔF_t	ΔS_t	ΔF_t	ΔS_t	ΔF_t	ΔS_t	ΔF_t	ΔS_t	ΔF_t
$\alpha_{s,f}$									-0.082* (-4.979)	-0.057** (2.786)
ΔS_{t-1}	1.005** (19.069)		0.570** (8.843)	0.066 (0.606)	1.036** (19.849)		0.625** (7.961)	0.177* (1.857)	0.617** (8.137)	0.172* (1.816)
ΔS_{t-2}	-0.288** (-5.568)		-0.182** (-3.639)	-0.104 (-1.238)	-0.305** (-6.022)		-0.183** (-3.207)	-0.011 (-0.162)	-0.155** (-2.792)	0.008 (0.124)
ΔF_{t-1}		0.537** (11.572)	0.325** (8.238)	0.497** (7.478)		0.606** (13.835)	0.479** (7.277)	0.469** (5.870)	0.424** (6.588)	0.431** (5.375)
ΔF_{t-2}			0.163** (3.834)	0.066 (0.922)			-0.014 (-0.203)	-0.053 (-0.631)	-0.038** (-0.572)	-0.070 (-0.839)
$\overline{R}^2$	0.638	0.278	0.718	0.276	0.659	0.358	0.705	0.361	0.725	0.374
AIC	-5.281	-4.496	-5.524	-4.484	-4.332	-4.084	-4.470	-4.080	-4.537	-4.097
SC	-5.258	-4.484	-5.478	-4.438	-4.309	-4.072	-4.424	-4.034	-4.479	-4.04
$Q(20)$	49.131 [0.050]	34.17 [0.047]	26.388 [0.153]	32.848 [0.035]	28.180 [0.059]	31.106 [0.039]	26.262 [0.157]	20.49 [0.49]	19.22 [0.508]	25.488 [0.183]
$Q^2(20)$	97.45 [0.00]	39.72 [0.00]	105.77 [0.00]	43.37 [0.00]	30.351 [0.034]	65.736 [0.00]	33.320 [0.031]	8.44 [0.98]	52.884 [0.00]	75.602 [0.00]

See notes to Table 4.50.

Table 4.52: Root mean squared forecast errors of various forecasting models of the spot prices for Capesize vessels

Route	Horizon	Number of Forecasts	VECM	VAR	ARMA	Random Walk
C4	1	148	0.0147	0.0148	0.0149	0.0206
	2	74	0.0296	0.0297	0.0299	0.0379
	3	49	0.0451	0.0453	0.0454	0.0528
	5	29	0.0677	0.0672	0.0700	0.0777
	10	14	0.1222	0.1203	0.1196	0.1305
	15	9	0.1767	0.1752	0.1642	0.1775
	20	7	0.2502	0.2426	0.2422	0.2383
C7	1	148	0.0193	0.0186	0.0195	0.0261
	2	74	0.0396	0.0368	0.0402	0.0483
	3	49	0.0577	0.0527	0.0579	0.0676
	5	29	0.0962	0.0837	0.0938	0.1033
	10	14	0.1789	0.1659	0.1511	0.1743
	15	9	0.2876	0.2664	0.2363	0.2522
	20	7	0.4165	0.3462	0.3303	0.3312

Table 4.53: Root mean squared forecast errors of various forecasting models of the forward prices for Capesize vessels

Route	Horizon	Number of Forecasts	VECM	VAR	ARMA	Random Walk
C4	1	148	0.0109	0.0110	0.0113	0.0130
	2	74	0.0200	0.0201	0.0205	0.0230
	3	49	0.0292	0.0297	0.0303	0.0320
	5	29	0.0425	0.0421	0.0424	0.0467
	10	14	0.0765	0.0758	0.0763	0.0808
	15	9	0.1115	0.1148	0.1150	0.1167
	20	7	0.1545	0.1453	0.1455	0.1446
C7	1	148	0.0142	0.0145	0.0146	0.0162
	2	74	0.0256	0.0269	0.0271	0.0283
	3	49	0.0322	0.0342	0.0349	0.0368
	5	29	0.0459	0.0481	0.0501	0.0568
	10	14	0.0926	0.0895	0.0936	0.0978
	15	9	0.1560	0.1470	0.1495	0.1511
	20	7	0.2363	0.1611	0.1634	0.1528

Table 4.54: Root mean squared forecast errors of various forecasting models of spot prices for Panamax vessels

Route	Horizon	Number of Forecasts	VECM	VAR	ARMA	Random Walk
P2A	1	148	-	0.0093	0.0104	0.0202
	2	74	-	0.0199	0.0233	0.0388
	3	49	-	0.0339	0.0375	0.0573
	5	29	-	0.0685	0.0692	0.0851
	10	14	-	0.1433	0.1405	0.1537
	15	9	-	0.2109	0.2065	0.2162
	20	7	-	0.1587	0.1646	0.1790
P3A	1	148	0.0189	0.0175	0.0180	0.0340
	2	74	0.0416	0.0350	0.0361	0.0643
	3	49	0.0758	0.0648	0.0682	0.0912
	5	29	0.1364	0.1231	0.1314	0.1416
	10	14	0.2076	0.1707	0.1713	0.1831
	15	9	0.2857	0.2399	0.2513	0.2705
	20	7	0.2877	0.1873	0.2030	0.2361

Table 4.55: Root mean squared forecast errors of various forecasting models of the forward prices for Panamax vessels

Route	Horizon	Number of Forecasts	VECM	VAR	ARMA	Random Walk
P2A	1	148	-	0.0393	0.0145	0.0203
	2	74	-	0.0288	0.0289	0.0371
	3	49	-	0.0451	0.0459	0.0544
	5	29	-	0.0770	0.0780	0.0810
	10	14	-	0.1254	0.1265	0.1328
	15	9	-	0.1938	0.1941	0.1915
	20	7	-	0.1484	0.1368	0.1523
P3A	1	148	0.0201	0.0194	0.0198	0.0266
	2	74	0.0372	0.0344	0.0355	0.0478
	3	49	0.0577	0.0540	0.0550	0.0683
	5	29	0.1017	0.0944	0.0958	0.1011
	10	14	0.1572	0.1400	0.1404	0.1517
	15	9	0.2354	0.2120	0.2107	0.2195
	20	7	0.2263	0.1658	0.1684	0.1988

Consider first the spot price forecasts for Capesize vessels in Table 4.52. On the route C4, the RMSEs of the VECM and the VAR specifications are almost identical for the forecast horizons up to 5 days ahead. Comparing the performance of these time series models against the benchmark RW model, we can see that time series models outperform the RW model for up to 15 days ahead. For the 20-days horizon, the gain in forecasting accuracy of the RW model over the VECM is statistically significant. Furthermore, Both the VEC and the VAR models seem to perform better than the ARMA model for the forecasting horizons up to 5 days ahead. This pattern in the forecasting performance of forward prices corresponds to the delivery cycle of a forward contract. Forward prices can help improve the forecasting performance for a horizon which does not extend beyond the expiry day of a forward contract.

On the route C7, results reveal that the VAR model outperforms the VECM for all the forecasting horizons. Because the coefficient of the error correction term of spot prices in the VECM model is insignificant at the conventional levels, the VECM will not help improve the forecasting performance of spot prices. The VAR outperforms the ARMA model up to 10 days ahead The ARMA model outperforms the RW for all horizons.

Consider the spot price forecasts for Panamax vessels in Table 4.54. On the route P2A, the VAR model performs better than the ARMA for all horizons, because the VAR model containing forward prices may generate forecasts more accurately than others. Furthermore, both VAR and ARMA models outperform the random walk model. On the route P3A, it is not found that the VECM outperforms the VAR model in the forecast horizons. This is expected since the coefficients of ECTs of both spot and forward equations are significantly negative. It means a positive forecast error at period t-1 will force both forward and spot prices to decrease, thus the disequilibrium cannot be eliminated. This finding might be attributed to the short estimation period. These tests should be performed again when more data are available. As a result, we cannot find the contribution of the ECT in enhancing prediction accuracy. For other models, it can be seen that the VAR model outperforms both the ARMA and RW models for all forecasting horizons.

Turning next to the perpetual forward price forecasts in Table 4.53 and Table 4.55, it can be seen that the VECM produces better forecasts than other models up to 5 days ahead on routes of C4 and C7, while on P3A, the forecasts generated by the VECM seem not be significantly more accurate than the forecasts obtained by other models. The VAR model seems to outperform the ARMA and random walk model for the horizons up to 15 days ahead on routes of C4 and C7, and for P2A and P3A, the random walk model performs the worst compared to VAR and ARMA models for all forecasting horizons. Furthermore, the VAR model seems to give better forecasts than the ARMA up to 10 days ahead. Spot prices, therefore can help to forecast forward prices more accurately.

It can be concluded that the forecasting performance of various models depends on forecasting horizons and on different segments.

4.6. Conclusions

This chapter presents the analysis and modelling of shipping prices in the dry bulk market by making use of the econometric methodology, through which substantial results are obtained.

The results regarding dynamic volatilities of spot and time-charter rates in Section 4.1 show that during the sample period from Jan 1990 to Dec 2010, the assumption of homoskedasticity employed under OLS, cannot be rejected at the conventional levels for one-year time-charter rates for three types of vessels, while heteroskedasticity is observed in return series of spot and three-year time-charter rates for three types of vessels during the sample period, a common finding with other financial series using high frequency data (Bollerslev *et al*.,1992). Volatilities are observed to be clearly different between the periods before and after 2003, after which a high volatility clustering is clearly observed in the return series. Additionally, the volatilities in Capesize, Panamax and Handymax markets tend to be affected by common external shocks, and in the meantime, influenced by its own factors of each market.

The empirical results in Section 4.2 reveal that the expectations theory seems not to hold for the period of Jan 1990 to Dec 2010 for three types of vessels and the failure of assumptions may attribute to the existence of the risk premium in the freight market. Furthermore, the risk premium may be time varying and market dependent in Capesize and Panamax markets, while in the Handymax market, only constant risk premium is observed.

However, there are potential weaknesses in the data material and challenges in the structure of this analysis that generally preclude robust conclusions about the magnitude and dynamics of the risk premium. The published TCE spot freight rates may not be representatives for the ‘true’ earnings in the spot market because it’s the average of all available spot rates. The present value model is constructed due to the assumption that the vessel is always hired for one month. While practically the duration of a trip-charter can be diverse given the large number of trading routes available to dry-bulk vessels, the published TCE spot freight rates will be biased compared to the true spot earnings, which would cause the estimated implied risk premium to be biased. Most importantly, without a transparent, liquid, and organized market for the forward freight or futures contracts in the bulk shipping, it is the illiquid and heterogeneous physical period charter market that defines the term structure of freight rates. Accordingly, it is generally impossible to draw robust conclusions about the magnitude and sign of the implied risk premium or the market efficiency in the freight markets for three types of vessels on this basis. However, large deviations from the proposed relationship are not very likely, as this would imply that investors have very different opinions as to the prevailing market price for a ship.

Section 4.3 examines the lead-lag relationships in daily returns and volatilities between Capesize and

Panamax prices and those between Panamax and Handymax prices in four routes: the transatlantic, the fronthaul, the transpacific and the backhaul routes. The whole sample period has been split into three sub ones due to shifting market conditions. Results indicate that information transmission between segments of Capesize and Panamax changes over time, and it is the same case for segments of Panamax and Handymax. The relationships in terms of returns and volatilities are found to be different in each sub period, and the trading activity or pattern in each trading route in each market changes as well.

Section 4.4 deals with the examination of the price discovery properties of dry bulk freight forward prices by testing the unbiasedness hypothesis and the lead-lag relationship between the freight forward and spot rates. The research on the unbiasedness hypothesis in the freight forward markets of dry bulk vessels focuses on the routes C4, C7, P2A, P3A, TCC, TCP and TCH during 2005 to 2010. The results from testing the unbiasedness hypothesis indicate that freight forward prices one month prior to maturity are unbiased estimators of the realized spot prices for almost all the routes with the exception of TCH for Handymax vessels at the 10% significance level. For horizons of two months and three months prior to maturity, the unbiasedness hypothesis is found at all routes.

The lead-lag relationship between spot prices and forward prices of dry bulk shipping market is also examined on the most liquid dry bulk freight forward contracts on routes C4, C7, P2A and P3A during the period 4th Jan 2005 to 24th Dec 2010. Due to possible structural breaks during the investigated period, the whole sample period is then divided into three sub periods. The main findings are that forward prices seem to lead spot rates in all the investigated routes in three sub periods. And there is a two-way feed back causal relationship between both price series in most cases at the 10% significance level, but the effect is stronger from the forward market to the spot market. Exceptions can be found on the route P2A during the second sub-period and C4 during the third period, where only unidirectional causality effect is detected from the forward market to the spot market.

Section 4.5 presents the investigation into the prediction of spot rates in the spot freight market and the forecasting performance of FFA prices in the forward market.

Results on the forecasting of spot rates on the main trading routes in Capesize, Panamax and Handymax markets show that the one-month index change during the current period contains information of the potential underlying demand change and the market sentiment, and has the substantial impact on the market movement next period. The US Dollar index and the exchange rate of US Dollar against EUR are also found to have the significant impact on spot prices. These variables are regarded as exogenous variables and therefore included into models. All the spot prices cover the period from Jan 1990 to Dec 2010, which is split into an estimation period and an out-of-sample forecasting period. In order to test whether the market since 2003 is significantly different from the market before, the in-sample estimation is made over two sample periods. Various models are estimated firstly over the whole period from Jan 1990 to June 2009 and then estimated again over the second period from Jan 2003 to June 2009 for all routes in three ship size markets. The period from July 2009 to Dec 2010 is then used to evaluate independent out-of-sample forecasts.

The findings of forecasting models suggest that with the indicator of one-month index change incorporated, a vector auto regression (VAR) model and a vector auto regression with exogenous variables (VARX) model perform well on the out-of-sample forecast against the univariate auto regressive integrated moving average (ARMA) model and univariate auto regressive integrated moving average with exogenous variables(ARMAX). And the VARX model estimated during the second period of Jan 2003 to June 2009 performs the best for the one-period ahead forecasts on all routes for three types of vessels. For the two-period ahead and the three-period ahead forecasts, the VAR model of the second period (2003:01-2010:06) outperforms that of the whole estimation period (1990:01-2010:06) only in the Capesize market, while in Panamax and Handymax markets, there is no strong evidence showing that the VAR model estimated during the second period can produce better forecasts than the VAR model estimated during the whole period.

The investigation on the forecasting ability of monthly forward prices implies that the forward prices contain valuable information about future spot rates. The FFA prices one month prior to the maturity for forward contracts of TCC, TCP and TCH, and the underlying monthly spot prices in each ship size market are employed in the forecasting models. Time-series models are generally found to perform worse than the forecasts indicated by the forward prices themselves for the one-month horizon, which are consistent with the acceptance of the unbiasedness hypothesis at the investigated routes.

The examination on the forecasting ability of daily forward prices reveals as well that the adjusted forward prices contain useful information regarding the future trends of daily spot prices, which can help to improve the forecasting performance of spot prices on the investigated routes. Comparing various forecasting models, results imply that at shorter horizons, the VECM with significant coefficients of error correction terms of opposite signs can give better results of forecasting spot and forward prices than other models, among which the VAR performs better than the ARMA. While for longer horizons, the ARMA model seems to outperform the VAR and the VECM models.

Chapter 5. Modelling Price Behavior in the New-building Ship Market

The newbuilding ship market trades ships which do not exist. Stopford (2004) argues that in this market, the specification of ships must be determined. Although shipyards sell standard vessels, most ships are designed, at least to a certain extent, to buyers' specification. Usually it will take around two years to build new vessels, during which the market conditions may have changed.

Stopford (2004) argues that motives for buyers to enter the newbuilding market are diverse. For instance, large shipping companies usually have the plan of regular replacement of obsolete vessels, or they may need additional tonnages to meet the expected increasing demand of transportation. Sometimes ships of certain specifications are needed for industrial projects required by steel mills, power stations, etc, and these vessels may not be available in the second-hand ship market. Another possibility is that when second-hand ship prices are higher than the price of a newbuilding, investors in the ship market may shift to the newbuilding sector. Finally, speculators may be attracted by low ship prices and favorable policies provided by ship yards and/or by the government, such as favorable credit policies and shipbuilding subsidies.

Despite different motives, the demand for new vessels usually reflects the need for the sea transportation and the ship-owners' expectations of future prices in the freight market. The limited previous research on the newbuilding market includes Beenstock (1985), Beenstock and Vergottis (1989), Jin (1993) and Kavussanos and Alizadeh (2002b) among others, which can be seen in Chapter 3 for more details. The previous research reveals that prices of new building vessels are primarily determined by freight rates, prices in the second-hand and scrap markets, and/or other exogenous economic variables, such as the exchange rate, interest rate, shipbuilding costs and the shipyard capacity.

The substantial attention in this chapter is given to several issues. The next section first examines volatilities of ship prices in the newbuilding market for three types of vessels. Section Two then studies relationships between newbuilding ship prices and charter rates in the freight market. Relationships between prices in the newbuilding, the second-hand, the scrap and the freight markets are further discussed in Section Three. Based on these studies, Section Four describes various forecasting models in the prediction of new ship prices and reports different forecasting performance of each model. Finally, the simulation-based optimization of ship designs based on specific projects is presented in Section Five.

5.1. The volatilities of ship prices in the newbuilding ship market

Ship-owners are very concerned about ship prices and their fluctuations over time when they take decisions regarding the buying and selling of vessels. If variances of new ship prices vary over time, the risk of investment in the new ship market may also change over time and vice versa.

The past research on examining ship prices primarily focuses on modelling the ship price level and only a limited number of studies focus on the time varying variance of monthly ship prices, examples are Kavussanos (1996a), Kavussanos (1996b) and Kavussanos (1997) among others. It is argued by

Kavussanos that ship-owners are interested in measures of risk in conjunction with returns when selecting the type of assets to be included into their portfolios of shipping assets. A comparison of time-varying risks between various size vessels will help ship-owners for example, to measure risks of investment in different ship markets towards ship sizes. Understanding the dynamics of volatility for each ship-size can help predict the variance and consequently result in more precise forecast intervals around ship prices.

5.1.1. Methodology

If the conditional time-varying variation exists for returns of newbuilding prices, GARCH models will be used to check the dynamic behavior of return series, because the GARCH formulation captures the tendency for volatility clustering, i.e. the tendency for large/small swings in prices to be followed by large/small swings of random direction. Another reason why GARCH models are useful when dealing with high frequency data is that the distributions of these data are leptokurtic, see Kavussanos (1997).

Among GARCH models, a GARCH$(1,1)$ model will be chosen, since it has been shown to be a parsimonious representation of the conditional variance that can be adequately used to model many economic return series. The specification of a GARCH$(1,1)$ model can be expressed as Equation (4.1). In order to examine the effect of the changing market conditions, a GARCH$(1,1)$ -X model, described as Equation (4.2) has been utilized.

5.1.2. Description of data and statistical properties

Monthly newbuilding prices examined in this part are those for Capesize vessels of 176,000-180,000 dwt, Panamax of 75,000-77,000 dwt and Handymax of 56,000-58,000 dwt, respectively. All of these figures are obtained from Clarkson Research Studies Ltd. Because newbuilding prices for Capesize of 176,000-180,000 dwt are only available since Jun 1986, the sample period is set from Jun 1986 to Dec 2010. Trends of newbuilding ship prices over time can be shown in Figure 5.1.

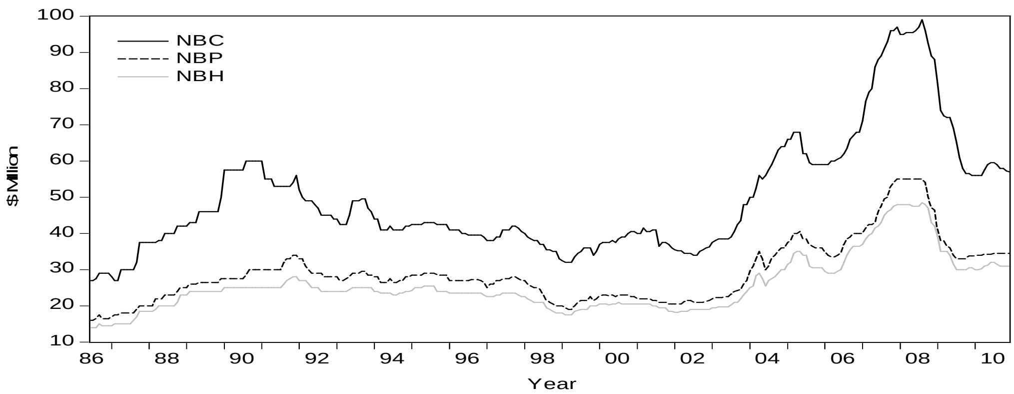

Figure 5.1: Newbuilding prices during Jun 1986 to Dec 2010 for three types of vessels

Notes: NBC=newbuilding ship prices for Capesize; NBP=newbuilding ship prices for Panamax; NBH=newbuilding ship prices for Handymax

The summary statistics of monthly rates of price changes in logarithmic new ship prices over the sample period are in Table 5.1. The results indicate that the mean values of monthly returns of bigger vessels seem to be lower than smaller ones. A comparison between sample standard deviations reveals that though the value of the standard deviation for Capesize is slightly larger than the other two sizes, the Capesize variation over the entire period is not significantly higher than that of Panamax at the 5% conventional level by the equality test shown in the same table. The equality test also shows that the hypothesis of the

Panamax variation equal to Handymax cannot be rejected statistically. However, a significantly larger variance for Capesize vessels can be found compared to that for Handymax. The leptokurtic property of the sample distributions of monthly returns is evident in the summary statistics, and the Jarque and Bera (1980) tests indicate significant departures from normality for all time series.

The Ljung-Box Q(20) statistics (Ljung-Box, 1978) of the stationary series reveal high degrees of serial correlation in the conditional means of the variables. The Ljung-Box $Q^2(20)$ statistics (Ljung-Box, 1978) demonstrate the existence of heteroskedasticity for returns of Panamax and Handymax vessels at the 5% significance level, while no heteroskedasticity can be found for returns of Capesize vessels at the conventional levels. Further investigation of volatilities of each size should be made by time series models.

Table 5.1: Descriptive statistics of monthly returns of the newbuilding prices for three types of vessels

	ΔNBC	ΔNBP	ΔNBH
N	294	294	294
Mean	0.0025	0.0026	0.0027
Median	0.000	0.000	0.000
Std. Dev.	0.030	0.028	0.026
Equality test*	1.07	1.077	1.15
Skewness	0.558[0.00]	-0.369[0.00]	-0.180[0.21]
Kurtosis	8.255[0.00]	5.776[0.00]	6.875[0.00]
Jarque-Bera	353.588[0.00]	101.109[0.00]	185.552[0.00]
Q(20)	91.78	112.58	105.79
$Q^2(20)$	17.78	53.87	41.33
ADF(lags) (Lev)	-1.89(1)	-2.19(2)	-2.21(1)
PP(lags) (Lev)	-2.00(10)	-2.28(11)	-2.26(6)
ADF(lags) (1st diffs)	-9.03(1)	-8.47(1)	-11.62(0)
PP(lags) (1st diffs)	-13.19(4)	-12.94(9)	-12.41(6)

Notes:

- ♦ ΔNBC means the logarithmic first differences for Capesize, ΔNBP the logarithmic first differences for Panamax, and ΔNBH the logarithmic first differences for Handymax.
- ♦ N is the number of observations; Figures in square brackets [·] indicate exact significance levels
- ♦ Skew and Kurt are the estimated centralized third and fourth moments of the data; their asymptotic distributions under the null are $T\hat{\alpha}_3^{'}\hat{\alpha}_3 / 6 \sim \chi^2(1)$ and $T(\hat{\alpha}_4 - 3)^{'}(\hat{\alpha}_4 - 3)/24 \sim \chi^2(1)$ respectively.
- ♦ Q(20) and $Q^2(20)$ are the Ljung and Box (1978) Q statistics on the first 20 lags of the sample autocorrelation function of the raw series and of the squared series; these tests are distributed as $\chi^2(20)$. The critical values are 37.57 and 31.41 for the 1% and 5% levels, respectively.
- ♦ J-B is the Jarque-Bera (1980) test for normality, distributed as $\chi^2(2)$
- ♦ ADF is the Augmented Dickey and Fuller (1981) test. PP is the Philips and Perron(1988) test; the truncation lag for the test is in parentheses. The 5% critical value for the ADF and PP tests is -2.87; the 1% critical value for the ADF and PP tests is -3.45.
- ♦ * The hypothesis of equality of the unconditional variances of returns between pairs of vessels can be tested using the statistic $F = V_1 / V_2 \sim F(n-1, m-1)$, V_1 and V_2 are sample variances, n and m are the number of observations used to compute each variance. The F-statistic for Capesize versus Panamax is 1.07, for Panamax vs Handymax is 1.077, for Capesize vs Handymax is 1.15. Critical value of the statistic at the 5% level is 1.08.

5.1.3. Empirical results

Since significant serial correlation has been found for returns of ship prices, time series ARMA model may then be fitted to model these conditional means for three types of vessels. The AIC and SBIC criteria have been employed to choose the lag length of the ARIMA model in the mean equation. The GARCH (1,1) model is used to investigate variance characters of residuals of the ARMA model if heteroskedasticity is observed to exist for the residuals.

Results in Table 5.2 reveal that serial correlation can be captured by the lagged returns of series for each ship size. Hetersckedasticity cannot be observed for residuals of Capesize and Panamax by both the Ljung-Box $Q^2(20)$ statistic and the ARCH test, while for Handymax the Ljung-Box $Q^2(20)$ statistic rejects the hypothesis of homoscedasticity, but this hypothesis cannot be rejected by Engle's ARCH test at the 5% significance level. Consequently, we may say generally there is no time-varying variation of returns for three types of vessels, implying that the new-building market is not sensitive to the market shocks, either new or old news. In the newbuilding market, investors always depend on the expected market conditions to make the decision to build a new vessel, the current market innovations therefore may not have an impact on the variation of newbuilding ship prices.

The analysis above shows that using monthly data to model returns of newbuilding ship prices requires lags of the dependent variables in order to take into account of the autocorrelation properties displayed in the means. The assumption of homoskedasticity, employed under OLS, cannot be rejected at the 5% significance level in these markets.

Table 5.2: Estimates of the mean and volatility of ship prices for dry bulk vessels

$$\Delta X_t = \varphi_0 + \sum_{i=1}^{p} \varphi_i \Delta X_{t-p} + \varepsilon_t,\ \varepsilon_t \sim iid(0, \Sigma)$$

Panel A: Estimates of various models

Capesize		Panamax		Handymax	
φ_0	-	φ_0	0.002 (1.209)	φ_0	0.002 (1.301)
φ_1	0.295** (5.301)	φ_1	0.347** (6.325)	φ_1	0.369** (6.803)
φ_4	0.161** (2.907)				

Panel B: Diagnostic tests on residuals of models for three types of vessels

	Capesize	Panamax	Handymax
J-B normality test	250 [0.00]	111.22 [0.00]	3016 [0.00]
$\bar{R}^2$	0.121	0.117	0.136
AIC	-4.26	-4.45	-4.58
SBIC	-4.23	-4.42	-4.56
Q(20)	16.52 [0.68]	30.53 [0.06]	23.14 [0.28]
$Q^2(20)$	24.06 [0.24]	22.67 [0.31]	36.69 [0.01]
ARCH (20)	23.95 [0.24]	19.14 [0.51]	29.41 [0.08]

Notes:

- All variables are transformed in natural logarithms.
- ** and * indicate significance at the 5% and 10% levels, respectively. Figures in parentheses (.) and in squared brackets [·] indicate t-statistics and exact significance levels, respectively.
- J-B Normality is the Jarque and Bera(1980) normality test, with probability values in square brackets.
- Q(20) and $Q^2(20)$ are the Ljung and Box (1978) tests for 20^{th} order serial correlation and heteroskedasticity in the standardized residuals and in the standardized squared residuals, respectively.
- ARCH(20) is the Engle's(1982) *F* test for Autoregressive Conditional Heteroskedasticity.

5.2. An empirical analysis of relationships between newbuilding prices and charter rates

The freight market and the newbuilding ship market are closely linked through economic relations, which are thought of influence of one market on the development of the other. It is clear that the price of a new vessel is related closely with the freight rate in the freight market. One the one hand, when the sea transport demand goes up, the freight rate will increase and the investment in newbuildings will be accelerated subsequently, finally leading to an increase in the new building price. On the other hand, building new vessels will increase the supply of tonnage in the dry bulk shipping market, and it therefore has a negative impact on charter rates in the freight market.

It can be seen from previous studies that time charter rates tend to be the determinant of newbuilding prices and there seem to be significant cointegration relationships between these two variables for three different ship types of dry bulk carriers. While most of the previous research on the newbuilding ship market focuses on the period before 2002, since which the dry bulk market has changed a lot characterized by sharper volatility and more speculative trading activities. Consequently, relationships between charter rates, including spot rates and time charter rates, and newbuilding ship prices are re-examined by extending the sample period to the end of 2010. To investigate relationships between these two markets is of great importance for shipping companies who may trade in these markets.

The remainder of this section is structured as follows. The next sub section outlines the methodology of examining relationships among variables. This is followed by an introduction of the data source and statistical properties. The final sub section presents the discussion of empirical results with implications of the findings.

5.2.1. Methodology

Cointegration test is used to investigate a long-run equilibrium relationship among variables. Johansen (1988, 1991) procedures for testing a long-run relationship among variables are the most reliable approaches and consequently preferred by researchers. The first step in examining the cointegration relationship between new-building ship prices and charter rates in different ship size markets, is to determine the order of integration of each price series using the Augmented Dickey-Fuller (ADF,1981) and Phillips and Perron (PP, 1988). Given a set of two I(1) series, the VECM (Johansen, 1988) is employed to make the estimation. The specification of a VECM model can be shown as follows and more details regarding the VECM can be seen in Appendix A.

$$\Delta X_t = \mu + \sum_{i=1}^{p-1} \Gamma_i \Delta X_{t-i} + \prod X_{t-1} + \varepsilon_t, \quad \varepsilon_t | \Omega_{t-1} \sim distr(0, H_t)$$

Here X_t is the 2×1 vector of log new building ship prices and log charter rates respectively. Δ denotes the first difference operator, ε_t is a 2×1 vector of error terms $(\varepsilon_{c,t}, \varepsilon_{p,t})'$, following an as-yet-unspecified conditional distribution with the mean zero and time-varying covariance H_t. Γ_i and $\prod$ are coefficient matrices. The VECM specification contains information on both the short- and long-run adjustment to changes in X_t via the estimates of Γ_i and $\prod$ respectively.

If newbuilding ship prices and charter rates are cointegrated, then causality must exist in at least one direction (Granger,1988). Granger causality can identify whether two variables move one after the other or contemporaneously. When they move contemporaneously, one provides no information for characterizing the other. If X causes Y, then changes in X should precede changes in Y, and vice versa.

5.2.2. Data description

The data set consists of spot earnings, one-year time charter rates and three-year time charter rates, generally called charter rates in the freight market, together with newbuilding ship prices in the ship market for dry bulk vessels. Prices for Panamax and Handymax vessels cover the period from Jan 1990 to Dec 2010, yielding a sample of 252 observations, and the sample period for Capesize vessels starts from Dec 1991 to Dec 2010 with 229 observations. Monthly charter rates and newbuilding ship prices for each ship size are all obtained from Clarkson Research Studies. Trends of all these variables can be shown in Figures 5.2-5.4. Some structural variables are selected to be included into econometric models to measure their impacts on newbuilding ship prices. These structural variables refer to the US dollar index, the 6-month US$ London Interbank Offered Rate (LIBOR) and the steel plate price in Japan. The US dollar index and the LIBOR during the sample period from Jan 1990 to Dec 2010 are obtained from a futures company in shanghai and Clarkson Research Studies, respectively. Since figures of steel prices from Clarkson Research Studies run from Aug 1999 to Dec 2010, figures from Jan 1990 to July 1999 are then obtained from the World Steel Dynamics. The summary statistics of logarithmic variables during the sample period are presented in Table 5.3.

Results of all price series in the freight and the new-building ship markets in Table 5.3 show that during the sample period, the mean values of spot earnings per day are higher than time charter rates, and additionally the mean level of time charter rates seems to be smaller as the period is longer. A comparison between sample standard deviations reveals that the spot earnings are more volatile than time charter rates, and time charter rates with long duration fluctuate less than that with short duration. Excess skewness and kurtosis are shown in all price series, with the exception of spot rates in all three markets and one-year timecharter rates in the Capesize market, which do not exhibit significant kurtosis. Data with excess kurtosis tend to have distinct peak near mean and drop quickly. The Jarque and Bera (1980) tests indicate departures from normality for all series. The Ljung-Box Q(20) and $Q^2(20)$ statistics (Ljung-Box, 1978) on the first 20 lags of the sample autocorrelation function of logarithmic first different series and of the squared series indicate significant serial correlation and the existence of heteroskedasticity, respectively. The existence of serial correlation in all series may result from the way shipbroking companies calculate the prices. As mentioned above, an assessment by the panelist is either made on an actual fixture or, in the absence of an actual fixture, made on previous day's level, which will induce autocorrelation in different rates. We use the Augmented Dicky-Fuller (ADF,1981) and Philips-Perron (PP,1988) unit root tests on the log levels and log-first differences of the price series to examine whether the series are stationary. The results show that all variables are non-stationary on log-levels and stationary on log first differences.

The results of newbuilding ship prices in Table 5.3 reveal that during the sample period, the mean values of newbuilding ship prices seem to be higher for larger vessels than smaller ones, as expected. Meanwhile, a larger standard deviation could be observed for larger vessels than smaller ones. Newbuilding ship price series exhibit excess skewness and kurtosis, rejecting the hypothesis of normality (skewness=0, kurtosis=3) in all cases. Serial correlation and heteroskedasticity are found by the Ljung-Box Q(20) and $Q^2(20)$ statistics for all types of vessels. The augmented Dickey-Fuller and Philips Perron unit root tests display that all the newbuilding prices are non-stationary on log-levels and stationary on log first differences. For economic indicators, all variables have a unit root on log-levels and are log-first difference stationary, displayed by the augmented Dickey-Fuller and Philips Perron unit root tests.

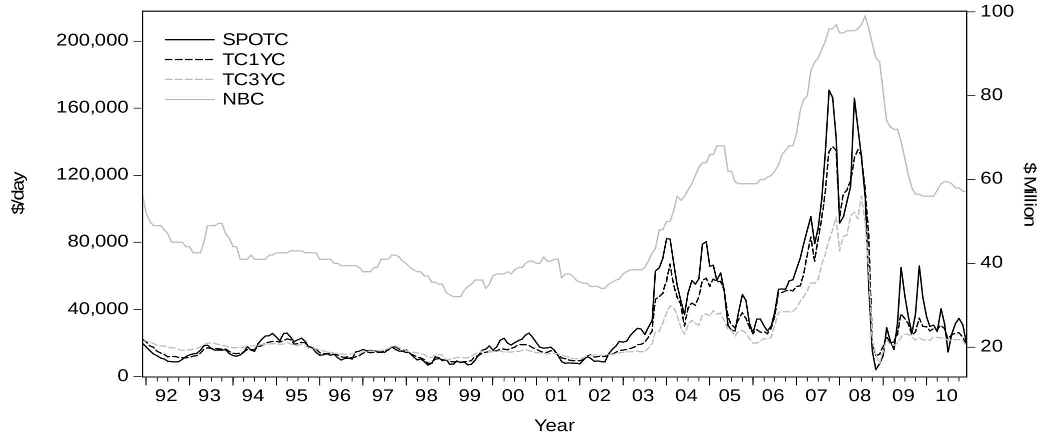

Figure 5.2: Newbuilding ship prices and charter rates for Capsize vessels during Jan 1991 to Dec 2010

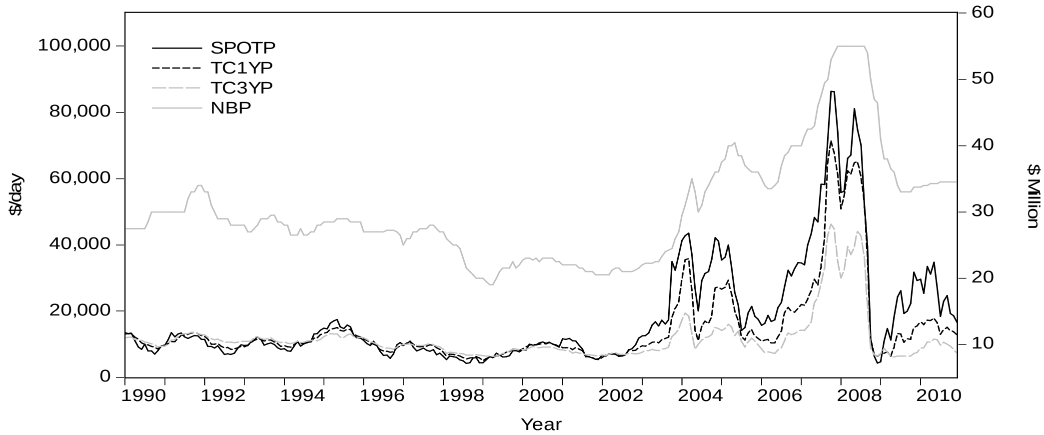

Figure 5.3: Newbuilding ship prices and charter rates for Panamax vessels during Jan 1990 to Dec 2010

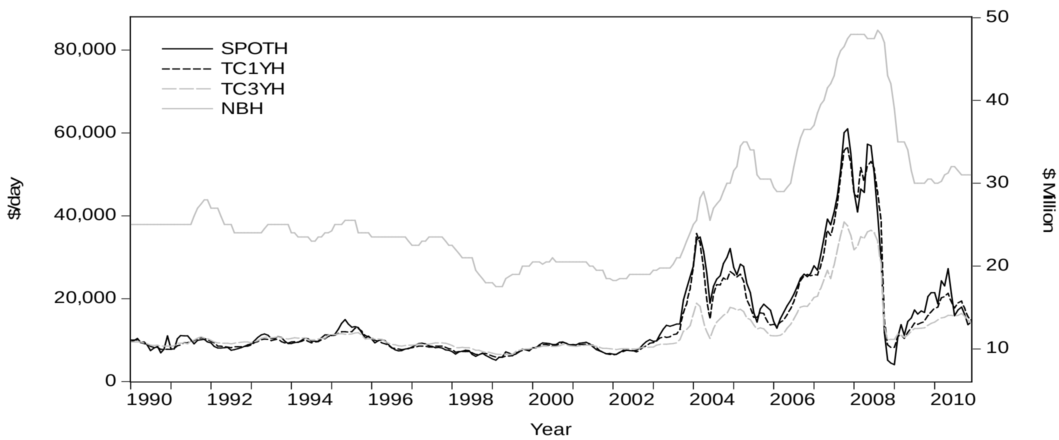

Figure 5.4: Newbuilding ship prices and charter rates for Handymax vessels during Jan 1990 to Dec 2010

Table 5.3: Descriptive statistics of logarithmic charter rates and newbuilding prices for three types of vessels and exogenous variables

	N	Mean	Median	Std. Dev.	Skewness		Kurtosis		Jarque-Bera		Q(20)	$Q^2(20)$	ADF(lags)	PP	ADF(lags)	PP
													Lev	Lev	1st diffs	1st diffs
The Capesize market																
Spot	229	10.035	9.886	0.772	0.624	[0.00]	2.709	[0.26]	15.69	[0.00]	1973.4	1637.2	-2.529(2)	-2.519(6)	-10.972(1)	-9.577(20)
TC1Y	229	9.987	9.770	0.678	1.012	[0.00]	3.297	[0.48]	38.89	[0.00]	2058.6	2023.8	-2.437(9)	-1.649(0)	-4.727(9)	-9.656(12)
TC3Y	229	9.923	9.809	0.517	1.370	[0.00]	4.553	[0.00]	94.69	[0.00]	1802.4	1772.7	-2.049(3)	-2.307(3)	-9.578(2)	-8.848(16)
NBC	229	3.89	3.761	0.297	0.832	[0.00]	2.706	[0.00]	27.23	[0.00]	3426	3394	-1.258(2)	-1.243(9)	-6.910(1)	-11.715(9)
The Panamax market																
Spot	252	9.522	9.336	0.690	0.747	[0.00]	2.824	[0.64]	23.784	[0.00]	1425.8	1461.3	-3.343(3)	-2.807(5)	-13.769(0)	-13.79(3)
TC1Y	252	9.397	9.266	0.541	1.402	[0.00]	5.036	[0.00]	126.09	[0.00]	1406.1	1388.9	-3.362(1)	-2.739(5)	-9.574(1)	-9.313(3)
TC3Y	252	9.264	9.220	0.404	1.674	[0.00]	6.453	[0.00]	242.94	[0.00]	1204.6	1200.9	-3.593(1)	-2.185(3)	-9.392(1)	-8.805(13)
NBP	252	3.38	3.35	0.253	0.618	[0.00]	3.036	[0.00]	16.063	[0.00]	3458	3407	-1.248(1)	-1.443(9)	-10.39(0)	-10.979(7)
The Handymax market																
Spot	252	9.419	9.218	0.571	0.936	[0.00]	3.130	[0.54]	36.97	[0.00]	2059.7	2058.6	-2.718(1)	-2.328(3)	-10.849(0)	-10.276(13)
TC1Y	252	9.388	9.181	0.540	1.210	[0.00]	3.668	[0.01]	66.19	[0.00]	2334.4	2282.6	-2.496(1)	-1.927(3)	-8.933(0)	-8.236(16)
TC3Y	252	9.321	9.217	0.388	1.499	[0.00]	4.933	[0.00]	133.57	[0.00]	2313	2267.2	-2.508(1)	-1.936(3)	-9.178(1)	-8.417(14)
NBH	252	3.25	3.219	0.252	0.831	[0.00]	3.15	[0.00]	29.249	[0.00]	3654	3609	-1.124(1)	-1.303(9)	-10.348(0)	-11.100(8)
USDX	252	4.269	4.885	2.087	-0.203	[0.19]	2.179	[0.01]	8.808	[0.01]	3017.5	3033.1	-1.971(1)	-1.629(3)	-10.36(1)	-10.96(4)
LIBOR	252	4.513	4.495	0.112	0.497	[0.00]	2.833	[0.59]	10.65	[0.01]	2256.5	1869.3	-1.521(2)	-1.569(8)	-7.725(1)	-11.674(5)
STEEL	252	6.096	5.913	0.365	1.036	[0.00]	3.408	[0.19]	46.88	[0.00]	3174	3087	-1.272(1)	-1.369(8)	-10.341(0)	-10.688(6)

Notes:

- All prices are transformed into logarithms
- NBC, NBP and NBH mean logarithmic newbuilding prices for Capesize, Panamax and Handymax. USDX, LIBOR and STEEL refer to the logarithmic US dollar index, the logarithmic LIBOR rate and the logarithmic steel price. All variables are transformed into logarithmics.
- N is the number of observations
- Q(20) and $Q^2(20)$ are the Ljung and Box (1978) Q statistics on the first 20 lags of the sample autocorrelation function of the raw series and of the squared series; these tests are distributed as $\chi^2(20)$ .The critical values are 37.57 and 31.41 for the 1% and 5% levels, respectively.
- Lev and 1st diffs refer to price series in log-levels and log-first differences, respectively. The 5% critical value for the ADF and PP tests is -2.869; the 1% critical value for the ADF and PP tests is -3.447.
- See other notes to Table 5.1.

5.2.3. Empirical analysis

Cointegration tests are made between charter rates and newbuilding ship prices for three size bulk carriers during the sample period. A VECM model is employed to estimate parameters of each equation, and a VECM-X model is used to measure impacts of some economic indicators on newbuilding ship prices.

5.2.3.1.Cointegration between newbuilding ship prices and charter rates

Having identified that charter rates and ship prices in three ship size markets are all $I(1)$ variables, the Johansen (1988) procedure is employed, in order to test for cointegration in all cases. The Schwartz Bayesian Information Criterion (Schwarz, 1978), Akaike Information Criterion(AIC)(Akaike, 1973) and the LR test are used to determine the lag length in the models. The examination of the cointegration relationship is carried out during the sample period from Jan 1990 to Dec 2010 for Panamax and Handymax, while pairs for Capesize vessels are estimated during the sample period from Dec 1991 to Dec 2010. The estimated $\lambda_{\max}$ and λ_{trace} statistics in Table 5.4 show that charter rates and newbuilding ship prices are cointegrated at the conventional significance levels in all cases.

The estimation results of the VECM models are reported in Table 5.5 for Capesize and Panamax, and results of Handymax are presented in Table 5.6. The residual diagnostics tests, presented in Tables 5.5-5.6 demonstrate the existence of heteroskedasticity for residuals in some equations, therefore, the standard errors and t statistics of the estimated coefficients are adjusted by the White (1980) heteroskedasticity correlation.

In the Capesize market, the coefficient of the error correction term (ECT) of the ship price equation, which is the difference between charter rates and newbuilding ship prices, is observed to be statistically significant and negative at the 5% significance level for three pairs. While the error correction coefficient of the spot rate equation is found to be positive and significant at the 10% significance level for three pairs. This implies that both newbuilding ship prices and charter rates respond to the previous deviation and correct the disequilibrium. While Granger causality tests on these variables, illustrated in Table 5.5 show that the significant causality is found from newbuilding prices to spot rates and from newbuilding prices to three-year charter rates at the 5% significance level, while for the pair between newbuilding prices and one year charter rates, the causality effect runs from one year charter rates to newbuilding ship prices.

In the Panamax market, for the pair of newbuilding prices and spot earnings, the error correction coefficient in the ship price equation and that in the spot rate equation are both significant at the 5% significance level with opposite signs. It is the same case for the pair of newbuilding prices and three year charter rates. While for the pair of newbuilding prices and one year charter rates, only the error correction coefficient of ship equation is significant at 5% significance level. Granger causality tests on the short run interactions indicate that charter rates Granger cause newbuilding prices without the feedback effect in three cases.

In the Handymax market, the error correction term parameter of the spot rate equation is not significant at conventional levels, while the ECT coefficients of newbuilding price equations are all significant at the 5% level. For the interactions between variables, charter rates Granger cause newbuilding prices without the feedback effect in three cases.

The causality relationship between newbuilding prices and charter rates in each market can be found in Figure 5.5.

Table 5.4: Johansen (1988) tests for the number of cointegrating vectors between charter rates and newbuilding ship prices

	Lags	*Hypothesis (maximal)*		*Test statistic*	*Hypothesis (trace)*		*Test statistic*	*95% Critical values*		Cointegrating vector
		H_0	H_1	$\lambda_{\max}$	H_0	H_1	λ_{trace}	$\lambda_{\max}$	λ_{trace}	$\beta' = (1, \beta_1, \beta_2)$
The Capesize market										
NB/Spot	2	$r = 0$	$r = 1$	26.46	$r = 0$	$r = 1$	31.48	15.89	20.26	(1,1.16,-0.504)
		$r \leq 1$	$r = 2$	5.02	$r \leq 1$	$r = 2$	5.02	9.16	9.16	
NB/TC1Y	1,8,9	$r = 0$	$r = 1$	43.95	$r = 0$	$r = 1$	45.94	15.89	20.26	(1,1.49, -0.539)
		$r \leq 1$	$r = 2$	1.99	$r \leq 1$	$r = 2$	1.99	9.16	9.16	
NB/TC3Y	1	$r = 0$	$r = 1$	55.27	$r = 0$	$r = 1$	56.89	15.89	20.26	(1,2.86,-0.681)
		$r \leq 1$	$r = 2$	1.62	$r \leq 1$	$r = 2$	1.62	9.16	9.16	
The Panamax market										
NB/Spot	1	$r = 0$	$r = 1$	44.39	$r = 0$	$r = 1$	47.64	15.89	20.26	(1,1.13,-0.475)
		$r \leq 1$	$r = 2$	3.29	$r \leq 1$	$r = 2$	3.29	9.16	9.16	
NB/TC1Y	2	$r = 0$	$r = 1$	40.88	$r = 0$	$r = 1$	43.87	15.89	20.26	(1,2.57, -0.635)
		$r \leq 1$	$r = 2$	2.99	$r \leq 1$	$r = 2$	2.99	9.16	9.16	
NB/TC3Y	1	$r = 0$	$r = 1$	26.74	$r = 0$	$r = 1$	28.45	15.89	20.26	(1,5.79,-0.992)
		$r \leq 1$	$r = 2$	1.71	$r \leq 1$	$r = 2$	1.71	9.16	9.16	
The Handymax market										
NB/Spot	1	$r = 0$	$r = 1$	46.39	$r = 0$	$r = 1$	48.85	15.89	20.26	(1,2.11,-0.569)
		$r \leq 1$	$r = 2$	2.46	$r \leq 1$	$r = 2$	2.46	9.16	9.16	
NB/TC1Y	1	$r = 0$	$r = 1$	39.39	$r = 0$	$r = 1$	41.79	15.89	20.26	(1,2.09, -0.57)
		$r \leq 1$	$r = 2$	2.40	$r \leq 1$	$r = 2$	2.40	9.16	9.16	
NB/TC3Y	1	$r = 0$	$r = 1$	39.30	$r = 0$	$r = 1$	41.09	15.89	20.26	(1,3.64,-0.739)
		$r \leq 1$	$r = 2$	1.79	$r \leq 1$	$r = 2$	1.79	9.16	9.16	

Notes:

- Lags is the lag length of a VAR model; the lag length is determined using the SBIC (1978), AIC(1973) and LR tests. r represents the number of cointegrating vectors.
- $\lambda_{\max}(r, r+1) = -T\ln(1-\hat{\lambda}_{r+1})$ and $\lambda_{trace}(r) = -T\sum_{i=r+1}^{n}\ln(1-\hat{\lambda}_i)$ where $\hat{\lambda}_i$ are the estimated eigenvalues of the $\prod$ matrix in Eq.(1). Critical values are from Osterwald-Lenum(1992), Table1.
- Estimates of the coefficients in the cointegrating vector are normalized with respect to the coefficient of charter rates.
- The statistic for the parameter restrictions on the coefficients of the cointegrating vector is $-T[\ln(1-\hat{\lambda}_1^*) - \ln(1-\hat{\lambda}_1)]$ where $\hat{\lambda}_1^*$ and $\hat{\lambda}_1$ denote the largest eigenvalues of the restricted and the unrestricted models, respectively. The statistic is distributed as χ^2 with degrees of freedom equal to the total number of restrictions minus the number of the just identifying restrictions, which equals the number of restrictions placed on the cointegrating vector.

Table 5.5: Estimates of the VECM in the Capesize and Panamax markets

$$\Delta P_t = \sum_{i=1}^{p-1}\alpha_{1,i}\Delta P_{t-i} + \sum_{i=1}^{p-1}\beta_{1,i}\Delta TC_{t-i} + \gamma_1 Z_{t-1} + \varepsilon_{1,t}$$

$$\Delta TC_t = \sum_{i=1}^{p-1}\alpha_{2,i}\Delta P_{t-i} + \sum_{i=1}^{p-1}\beta_{2,i}\Delta TC_{t-i} + \gamma_2 Z_{t-1} + \varepsilon_{2,t}$$

Panel A: VECM model estimates

	Capesize						Panamax					
	ΔNB_t	ΔSP_t	ΔNB_t	$\Delta TC1Y_t$	ΔNB_t	$\Delta TC3Y_t$	ΔNB_t	ΔSP_t	ΔNB_t	$\Delta TC1Y_t$	ΔNB_t	$\Delta TC3Y_t$
$\gamma_{j,}\ j=1,2$	-0.043** (-5.182)	0.263** (2.366)	-0.052** (-5.195)	0.216** (3.915)	-0.049** (-4.969)	0.229* (1.757)	-0.050** (-6.177)	0.122** (2.22)	-0.042* (-3.284)	0.095 (1.171)	-0.017** (-2.99)	0.088** (2.085)
$\alpha_{j,1}, j=1,2$	0.163** (2.523)	1.106* (1.748)	0.176** (2.737)	0.771** (2.191)	0.236** (3.844)	0.822** (2.02)	0.210** (3.572)	-	0.172** (2.124)	0.912** (2.568)	0.249** (4.48)	-
$\alpha_{j,2}, j=1,2$	0.11* (1.703)	0.671 (1.172)							-	-0.386 (-1.274)		
$\alpha_{j,8}, j=1,2$			-	-								
$\alpha_{j,9}, j=1,2$			-0.106* (-1.777)	-								
$\beta_{j,1}, j=1,2$	-	0.406** (2.896)	0.021* (1.853)	0.473** (7.458)	0.013 (1.05)	0.492** (3.49)	0.019** (2.271)	0.317** (4.903)	0.046** (2.668)	0.203* (1.869)	0.096** (6.933)	0.534** (4.114)
$\beta_{j,2}, j=1,2$	-0.135* (-1.778)	-0.180** (-1.973)							-	-		
$\beta_{j,8}, j=1,2$			-	-0.265** (-4.241)								
$\beta_{j,9}, j=1,2$			0.029** (2.617)	0.379** (6.024)								
Causality test												
$\Delta P_t \rightarrow \Delta TC_t$	5.99	[0.05]	5.16	[0.16]	8.68	[0.00]	0.0002	[0.98]	3.53	[0.17]	1.06	[0.30]
$\Delta TC_t \rightarrow \Delta P_t$	3.268	[0.19]	7.89	[0.05]	0.91	[0.34]	5.16	[0.02]	17.60	[0.00]	48.08	[0.00]
Panel B: Residual diagnostics												
J-B test	116 [0.00]	290 [0.00]	81.68 [0.00]	5072 [0.00]	104 [0.00]	4709 [0.00]	48.16 [0.00]	1017 [0.00]	23.43 [0.00]	2554 [0.00]	57.54 [0.00]	1086 [0.00]
$Q(20)$	22.70 [0.30]	31.03 [0.06]	18.03 [0.58]	21.83 [0.35]	23.42 [0.27]	31.45 [0.05]	16.46 [0.69]	27.65 [0.12]	18.59 [0.55]	32.46 [0.04]	12.36 [0.90]	33.5 [0.03]
$Q^2(20)$	15.38 [0.75]	192.86 [0.00]	16.56 [0.68]	5.76 [0.99]	17.01 [0.65]	67.63 [0.00]	34.02 [0.03]	34.97 [0.02]	38.75 [0.00]	21.43 [0.37]	19.02 [0.52]	77.53 [0.00]
ARCH(20)	12.50 [0.89]	102.07 [0.00]	14.32 [0.81]	5.17 [0.99]	13.79 [0.84]	58.27 [0.00]	30.48 [0.06]	31.45 [0.05]	28.34 [0.10]	15.84 [0.73]	17.03 [0.65]	55.88 [0.00]
$\bar{R}^2$	0.24	0.18	0.27	0.31	0.24	0.25	0.32	0.09	0.31	0.18	0.34	0.26

Notes:
- All variables are transformed in natural logarithms.
- Δ means the first difference; P denotes ship prices generally; TC time charter rates generally;
- ** and * indicate significance at the 5% and 10% levels, respectively
- Figures in parentheses (.) and in squared brackets [·] indicate standard errors and exact significance levels, respectively
- J-B Normality is the Jarque and Bera(1980) normality test, with probability values in square brackets
- $Q(20)$ and $Q^2(20)$ are the Ljung and Box (1978) tests for 20th order serial correlation and heteroskedasticity in the standardized residuals and in the standardized squared residuals, respectively.
- ARCH(20) is the Engle's(1982) *F* test for Autoregressive Conditional Heteroskedasticity.

Table 5.6: Estimates of the VECM model in the Handymax market

$$\Delta P_t = \sum_{i=1}^{p-1} \alpha_{1,i} \Delta P_{t-i} + \sum_{i=1}^{p-1} \beta_{1,i} \Delta TC_{t-i} + \gamma_1 Z_{t-1} + \varepsilon_{1,t}$$
$$\Delta TC_t = \sum_{i=1}^{p-1} \alpha_{2,i} \Delta P_{t-i} + \sum_{i=1}^{p-1} \beta_{2,i} \Delta TC_{t-i} + \gamma_2 Z_{t-1} + \varepsilon_{2,t}$$

Panel A: VECM model estimates for Handymax						
	ΔNB_t	ΔSP_t	ΔNB_t	$\Delta TC1Y_t$	ΔNB_t	$\Delta TC3Y_t$
$\gamma_{j,}\ j=1,2$	-0.048** (-6.249)	0.118 (1.073)	-0.052** (-5.757)	0.086** (2.428)	-0.059** (-5.146)	0.109** (3.294)
$\alpha_{j,1},\ j=1,2$	0.196** (3.317)	-	0.17** (2.949)	-	0.192** (3.396)	-
$\beta_{j,1},\ j=1,2$	0.026* (2.652)	0.386** (2.838)	0.065** (4.752)	0.553** (9.518)	0.099** (5.08)	0.576** (9.843)
Causality test						
$\Delta P_t \rightarrow \Delta TC_t$	0.229	[0.63]	0.323	[0.57]	0.16	[0.69]
$\Delta TC_t \rightarrow \Delta P_t$	7.04	[0.00]	22.58	[0.00]	25.84	[0.00]
Panel B: Residual diagnostics						
J-B test	154.7 [0.00]	1943 [0.00]	124.7 [0.00]	19848 [0.00]	139 [0.00]	2714 [0.00]
$Q(20)$	19.15 [0.51]	19.10 [0.52]	22.91 [0.29]	31.53 [0.05]	21.51 [0.37]	21.96 [0.34]
$Q^2(20)$	30.15 [0.07]	80.72 [0.00]	18.72 [0.53]	3.30 [0.99]	19.57 [0.48]	2.85 [1.00]
ARCH(20)	22.30 [0.32]	70.89 [0.00]	15.89 [0.72]	2.74 [1.00]	15.68 [0.74]	2.37 [1.00]
$\bar{R}^2$	0.33	0.13	0.35	0.26	0.35	0.28

See notes to Table 5.5.

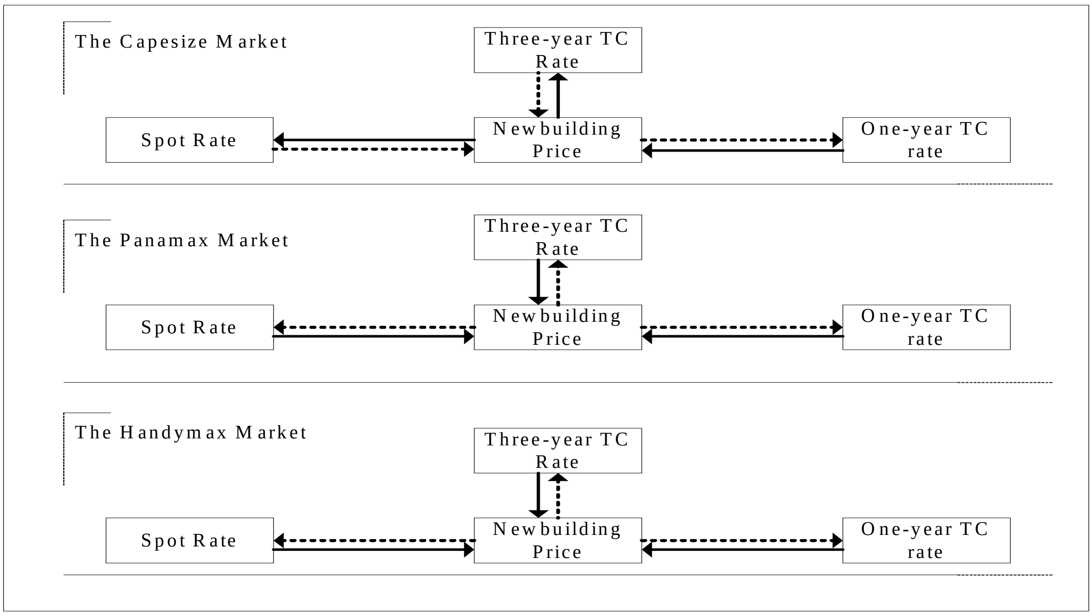

Figure 5.5: Relations between newbuilding ship prices and charter rates in three markets

Notes: the solid line with arrow denotes a significant causality relationship; the dash line with arrow indicates an insignificant causality relationship.

5.2.3.2.Further discussion of findings

The unidirectional causality from charter rates to new-building prices with the exception of two pairs for Capesize reveals that the freight market informationally leads the new-building market as expected, and charter rates have the predictive power in the prediction of new-building prices. In most cases, changes in new-building prices do not have any significant impact on changes of charter rates. Additionally, coefficients of lags of three-year time charter rates on the new-building equation are broadly larger in magnitude than those of one-year time charter rates and spot rates with the exception of Capesize vessels.

These findings can be explained by the underlying economic mechanism of both new-building market and the freight market. On the one hand, a decision to order a new-building vessel reflects shipping investors' expectations of future earnings in the freight market. Stopford (2009) points out that when the demand for sea transport increases, charter rates will rise and cash starts to pour in, allowing shipowners to pay higher prices for second-hand ships. As prices are bid up, investors turn to new-building vessels with comparatively better values. As a result, new-building vessel prices will finally be increased, stabilizing the shipping market with a barrier to excessive profits, see Dikos(2004). When charter rates start falling, the earnings in the freight market are squeezed, leading to an increase in the investment risk. This in turn requires a reduction in new-building prices. Therefore, charter rates can be considered as a determinant for prices of new-building vessels. Since it often takes more than a year and in some cases, two or three years, to build a vessel, shipowners need to make investment decisions based on the expectations of future earnings in the freight market. Period charter rates, rates of contracts for a number of consecutive periods, can be considered to contain information about future earnings of vessels during chartered periods. Therefore, shipowners prefer to refer to time charter rates with longer duration than spot earnings.

On the other hand, as Stopford (2009) argues that, although the economic structure of the shipbuilding market is closely linked to that of the shipping market, the shipbuilding market is a separate one, driven by more influences such as government policies, financial policies of banks, and the shipbuilding capacity. Events in the shipbuilding market, therefore, do not always mirror those of the shipping market, supporting the finding that new-building prices do not Granger cause charter rates in the freight market in most cases.

5.2.3.3. Impact of macroeconomic indicators on newbuilding ship prices

As discussed above, apart from charter rates, there are other factors which may have impacts on newbuilding ship prices.

Exchange rate

One the one hand, some new building costs are incurred in the local currency, but new ship prices are finally quoted in US dollars. The devaluation of the local currency against the US dollar, therefore, will have a negative impact on newbuilding prices. One the other hand, largest three shipbuilding countries, namely, Japan, Korea and China rely to a great extent on the imported raw materials, such as iron ore and coal, to build ships. The devaluated local currency will make shipyards pay more to buy raw materials. Building costs consequently will be increased and this will have a positive impact on new vessel prices. The overall effect will be examined.

Interest rate

Interest rates are used to measure the cost of capital of financing new ships. One the one hand, it is obvious that, ceteris paribus, high interest rates will impact negatively the demand for newbuilding ships and subsequently the price for new vessels, as shipowners will suffer higher financial expenses. On the other hand, during some periods, a rising interest rate may signify a rising world economy, which will increase the demand for shipping and push up prices of new vessels, and vice versa. Under such circumstances, changes of the interest rate would have a positive impact on those of newbuilding prices. Additionally, in the new ship market, there are always a lot of financing sources, as well as favorable government and shipyard credit policies available to investors to buy new vessels. The overall effect of the interest rate, therefore, is hard to say and needs to be investigated. The average 6-month US$ LIBOR rate is used in this chapter to make the analysis.

Steel price

Shipbuilding costs have a direct impact on newbuilding prices. Shipbuilding costs can be split up into material costs and labor costs, which are very difficult to measure, because they differ in different shipbuilding countries due to differences in shipbuilding technology, labor costs, etc. Because the cost spent in steel used of a new vessel may take up 20% to 30% of the total, we use the price of steel plates in Japan as a newbuilding cost indicator.

In order to examine impacts of these economic indicators on newbuilding ship prices, these exogenous variables are included into the VEC models for three pairs of each ship size. Because these variables are stationary on logarithmic first differences, and the examination of these economic indicators is for the prediction of new vessel ships, the lagged first differences of these economic indicators are included into the VECM, called the VECM-X model. Results of VECM-X models in the Capesize, the Panamax and Handymax markets can be found in Tables 5.7-5.9, respectively. Results show that these economic variables are not significant at the 10% significance level in the equation of newbuilding ship prices for three pairs of each ship size, with the exception of the LIBOR for two pairs for Handymax vessels.

The lagged US dollar index in the newbuilding ship equation of a VEC model is found to be statistically insignificant in all cases, implying that the overall effect of the appreciation or devaluation of the US dollar relative to other currencies in the previous period does not have any significant impact on newbuilding ship prices.

For the LIBOR, its coefficient in the newbuilding ship equation of a VEC model is observed to be significantly positive at the 5% significance level in the Handymax market for the pair between one-year time charter rates and newbuilding prices, and for the pair between three-year time charter rates and newbuilding prices. This indicates that the interest rate positively affect the determination of new ship prices for small vessels. While in other cases, it is not significant statistically.

For the steel price, it is found not to be significant in the newbuilding ship equation of the model. As an important part of ship-building costs, the steel price will definitely affect costs of new vessels. While changes in new-building costs sometimes would not be directly inflected by newbuilding prices. For instance, in order to make the newbuilding price competitive when the demand for new vessels remains low, ship yards will not always raise newbuilding prices when shipping costs are increased. This can partly explain why the lagged changes in the steel price will not influence new ship prices significantly.

Table 5.7: Estimates of the VECM-X model in the Capesize market

$$\Delta P_t = \sum_{i=1}^{p-1} \alpha_{1,i} \Delta P_{t-i} + \sum_{i=1}^{p-1} \beta_{1,i} \Delta TC_{t-i} + \gamma_1 Z_{t-1} + \sum_{n=1}^{q-1} k_{1,n} X_{n,t-1} \varepsilon_{1,t}$$

$$\Delta TC_t = \sum_{i=1}^{p-1} \alpha_{2,i} \Delta P_{t-i} + \sum_{i=1}^{p-1} \beta_{2,i} \Delta TC_{t-i} + \gamma_2 Z_{t-1} + \sum_{n=1}^{q-1} k_{2,n} X_{n,t-1} + \varepsilon_{2,t}$$

Panel A: VECM-X model estimates for the Capesize

	ΔNB_t	ΔSP_t	ΔNB_t	$\Delta TC1Y_t$	ΔNB_t	$\Delta TC3Y_t$
$\gamma_{j,}\ j=1,2$	-0.037** (-4.591)	0.292** (4.147)	-0.043** (-3.979)	0.243** (4.255)	-0.041** (-3.807)	0.293** (6.316)
$\alpha_{j,1},\ j=1,2$	0.153** (2.306)	1.185** (2.065)	0.161** (2.404)	0.853** (2.411)	0.218** (3.456)	0.659** (2.454)
$\alpha_{j,2},\ j=1,2$	0.099 (1.506)	0.611 (1.062)				
$\alpha_{j,8},\ j=1,2$			0.016 (0.241)	0.028 (0.08)		
$\alpha_{j,9},\ j=1,2$			-0.111* (-1.763)	0.163 (0.488)		
$\beta_{j,1},\ j=1,2$	0.008 (0.013)	0.393** (6.075)	0.025* (2.057)	0.435** (6.638)	0.017 (1.152)	0.500** (8.084)
$\beta_{j,2},\ j=1,2$	-0.014* (-1.785)	-0.107 (-1.571)				
$\beta_{j,8},\ j=1,2$			0.003 (0.275)	-0.239** (-3.883)		
$\beta_{j,9},\ j=1,2$			0.027** (2.316)	0.357** (5.652)		
$\Delta usdx_{t-1}$	-0.024 (-0.294)	-1.625** (-2.232)	-0.012 (-0.134)	-1.338** (-2.919)	-0.052 (-0.637)	-1.710** (-4.908)
$\Delta libor_{t-1}$	0.039* (1.686)	-0.534** (-2.827)	0.032 (1.536)	-0.150 (-1.323)	0.034 (1.553)	0.122 (1.316)
$\Delta steel_{t-1}$	-0.003 (-0.073)	0.823** (2.545)	0.007 (0.195)	0.29 (1.431)	0.010 (0.273)	0.468** (2.966)

Panel B: Residual diagnostic

J-B test	77.29 [0.00]	36.71 [0.00]	91.71 [0.00]	5824 [0.00]	103.84 [0.00]	1332 [0.00]
$Q(20)$	19.03 [0.52]	16.67 [0.67]	18.62 [0.55]	20.44 [0.43]	20.55 [0.42]	18.13 [0.58]
$Q^2(20)$	16.82 [0.66]	65.89 [0.00]	16.56 [0.68]	2.97 [1.00]	16.12 [0.71]	15.05 [0.77]
$\overline{R}^2$	0.236	0.25	0.25	0.35	0.23	0.34

Notes:
- All variables are transformed in natural logarithms.
- Δ means the first difference; P denotes ship prices generally; TC time charter rates generally;
- ** and * indicate significance at the 5% and 10% levels, respectively
- Figures in parentheses (.) and in squared brackets [·] indicate standard errors and exact significance levels, respectively
- J-B Normality is the Jarque and Bera(1980) normality test, with probability values in square brackets
- $Q(20)$ and $Q^2(20)$ are the Ljung and Box (1978) tests for 20th order serial correlation and heteroskedasticity in the standardized residuals and in the standardized squared residuals, respectively.

Table 5.8: Estimates of the VECM-X model in the Panamax market

$$\Delta P_t = \sum_{i=1}^{p-1} \alpha_{1,i} \Delta P_{t-i} + \sum_{i=1}^{p-1} \beta_{1,i} \Delta TC_{t-i} + \gamma_1 Z_{t-1} + \sum_{n=1}^{q-1} k_{1,n} X_{n,t-1} \varepsilon_{1,t}$$

$$\Delta TC_t = \sum_{i=1}^{p-1} \alpha_{2,i} \Delta P_{t-i} + \sum_{i=1}^{p-1} \beta_{2,i} \Delta TC_{t-i} + \gamma_2 Z_{t-1} + \sum_{n=1}^{q-1} k_{2,n} X_{n,t-1} + \varepsilon_{2,t}$$

Panel A: VECM-X model estimates for Panamax

	ΔNB_t	ΔSP_t	ΔNB_t	$\Delta TC1Y_t$	ΔNB_t	$\Delta TC3Y_t$
$\gamma_{j,}\ j=1,2$	-0.049** (-5.856)	0.119** (1.928)	-0.043** (-4.454)	0.160** (3.142)	-0.015** (-2.538)	0.096** (4.229)
$\alpha_{j,1},\ j=1,2$	0.208** (3.473)	-0.169 (-0.384)	0.163** (2.535)	0.221 (0.661)	0.244** (4.262)	0.122 (0.519)
$\alpha_{j,2},\ j=1,2$			0.067 (1.038)	0.390 (1.158)		
$\beta_{j,1},\ j=1,2$	0.017** (1.88)	0.296** (4.369)	0.046** (3.728)	0.516** (7.938)	0.096** (6.728)	0.518** (8.847)
$\beta_{j,2},\ j=1,2$			-0.005 (-0.404)	-0.099 (-1.397)		
$\Delta usdx_{t-1}$	-0.063 (-0.867)	-1.694** (-3.184)	-0.048 (-0.651)	-1.155** (-3.027)	-0.041 (-0.575)	-0.63** (-2.158)
$\Delta libor_{t-1}$	0.018 (0.913)	-0.212 (-1.506)	0.027 (1.36)	-0.027 (-0.268)	0.028 (1.54)	-0.042 (-0.607)
$\Delta steel_{t-1}$	-0.024 (-0.712)	0.176 (0.701)	-0.063 (-1.525)	-0.007 (-0.038)	0.001 (0.032)	0.24 (1.185)

Panel B: Residual diagnostic

J-B test	54.60 [0.00]	886 [0.00]	24.85 [0.00]	2387 [0.00]	56.94 [0.00]	1059 [0.00]
$Q(20)$	16.53 [0.68]	37.65 [0.12]	19.82 [0.47]	33.64 [0.03]	11.47 [0.93]	31.25 [0.04]
$Q^2(20)$	34.56 [0.05]	30.49 [0.06]	35.67 [0.03]	19.58 [0.48]	22.32 [0.33]	67.13 [0.00]
$\overline{R}^2$	0.31	0.13	0.31	0.27	0.34	0.28

See notes to Table 5.7.

Table 5.9: Estimates of the VECM-X model in the Handymax market

$$\Delta P_t = \sum_{i=1}^{p-1} \alpha_{1,i} \Delta P_{t-i} + \sum_{i=1}^{p-1} \beta_{1,i} \Delta TC_{t-i} + \gamma_1 Z_{t-1} + \sum_{n=1}^{q-1} k_{1,n} X_{n,t-1} \varepsilon_{1,t}$$
$$\Delta TC_t = \sum_{i=1}^{p-1} \alpha_{2,i} \Delta P_{t-i} + \sum_{i=1}^{p-1} \beta_{2,i} \Delta TC_{t-i} + \gamma_2 Z_{t-1} + \sum_{n=1}^{q-1} k_{2,n} X_{n,t-1} + \varepsilon_{2,t}$$

Panel A: VECM-X model estimates for the Handymax						
	ΔNB_t	ΔSP_t	ΔNB_t	$\Delta TC1Y_t$	ΔNB_t	$\Delta TC3Y_t$
$\gamma_{j,}\ j=1,2$	-0.044** (-5.566)	0.123** (2.502)	-0.048** (-5.21)	0.071* (1.80)	-0.059** (-4.779)	0.114** (2.991)
$\alpha_{j,1},\ j=1,2$	0.197** (3.229)	-0.320 (-0.842)	0.167** (2.81)	-0.094 (-0.369)	0.179** (3.061)	-0.068 (-0.377)
$\beta_{j,1},\ j=1,2$	0.023* (2.06)	0.444** (6.47)	0.066** (4.519)	0.525** (8.425)	0.102** (4.888)	0.561** (8.781)
$\Delta usdx_{t-1}$	-0.060 (-0.916)	-1.029** (-2.526)	-0.012 (-0.193)	-0.575** (-2.084)	-0.003 (-0.043)	-0.381* (-1.935)
$\Delta libor_{t-1}$	0.023 (1.29)	-0.292** (-2.62)	0.038** (2.188)	-0.123 (-0.166)	0.047** (2.77)	-0.044 (-0.848)
$\Delta steel_{t-1}$	-0.021 (-0.618)	0.495** (2.359)	-0.030 (-0.963)	0.037 (0.279)	-0.026 (-0.858)	0.084 (0.897)
Panel B: Residual diagnostic						
J-B test	174 [0.00]	1307 [0.00]	142.8 [0.00]	18642 [0.00]	154.28 [0.00]	27217 [0.00]
$Q(20)$	17.55 [0.617]	22.04 [0.338]	20.21 [0.445]	27.64 [0.118]	18.37 [0.54]	28.44 [0.10]
$Q^2(20)$	29.89 [0.07]	74.76 [0.00]	18.13 [0.58]	2.30 [0.99]	18.07 [0.58]	2.61 [0.99]
$\overline{R}^2$	0.32	0.19	0.36	0.28	0.37	0.28

See notes to Table 5.7.

5.3. Relationships between prices in the new-building, the second-hand, the scrap and the freight markets

In the dry bulk shipping industry, there are four central markets trading in different commodities. The freight market trades in sea transport of commodities and deals in ships for hire; the sale and purchase market deals in second-hand ships; the new-building market deals in new ships, and the demolition market trades in old ships for scrap. The latter three markets can also be called generally the ship market. All these markets are closely related by economic relations, which are thought of influence of the one market on the development of another.

Apart from the freight market, the newbuilding market is, to some extent, related with other ship markets, such as the second-hand ship market and the scrap market. Since the long-run relationships between newbuilding prices and charter rates have already been discussed in Section 5.2, it is interesting to check the short-term dynamics among variables in all of these markets. In this case, an alternative approach of investigating short-term dynamics is a VAR model, i.e. an autoregressive model for a vector of time series variables.

The VAR model is used to capture the evolution and interdependencies between multiple time series. All the variables in a VAR are treated symmetrically by including for each variable an equation explaining its evolution based on its own lags and the lags of all the other variables in the model. The purpose of employing VAR model is to examine the short-run dynamics among new-building prices, second-hand prices, scrap prices and charter rates for each size of bulk carriers. In order to examine impacts of exogenous variables on the endogenous variables, a VAR-X model will be employed and it becomes:

$$\Delta S_t = \mu + \sum_{i=1}^{p-1} \Psi_i \Delta S_{t-i} + \sum_{j=1}^{q-1} \Phi_j \Delta Z_{j,t-1} + \varepsilon_t, \qquad \varepsilon_t \big| \Omega_{t-1} \sim distr(0, H_t)$$

Where S_t is the 4×1 vector of log ship prices and log charter rates. Z_t is the $(r\times1)$ vector of exogenous variables. Δ denotes the first difference operator, ε_t is a 4×1 vector of error terms, following an as-yet-unspecified conditional distribution with mean zero and time-varying covariance H_t. Ψ and Φ are coefficient matrices. Akaike's information criteria (AIC) and Schwarz's criteria (SC) are also used to determine the lag length p and q.

Charter rates in this chapter include spot rates, one-year time charter rates and three-year time charter rates. These three types of charter rates will not be all incorporated into the VAR-X model, one of which will be selected to take as an instance. The Schwarz Bayesian Information Criterion (SBC; Schwarz, 1978) and the coefficient of determination ($\bar{R}^2$) are utilized to choose charter rates, which can reduce the value of SBC of a VAR-X model and improve the $\bar{R}^2$ value of each ship equation.

5.3.1. Description of the data and the statistical properties

The data set used consists of new-building ship prices, second-hand ship prices, scrap ship prices, charter rates, the US dollar index, the LIBOR and the steel price covering the period from Jan 1990 to Dec 2010, yielding a sample of 252 observations, and the sample period for Capesize vessels starts from Dec 1991 to Dec 2010 with 229 observations. Monthly prices for each ship size and economic variables are all obtained from Clarkson Research Studies. Because statistical properties of charter rates and economic variables have already been explained in section 5.2, they will not be introduced in this part.

Trends of new-building prices, second-hand prices and scrap prices are demonstrated in Figures 5.6-5.8. It can be seen clearly that newbuilding prices vary by vessel size but show similar stochastic behavior over time. It can be argued that these price series follow similar patterns and move together in the long run, but their short run behavior is not identical and shows different short term dynamics. The same conclusions could be drawn as well for second-hand prices and scrap prices. Comparing new-building prices to second-hand ship ones, we can find that second-hand prices are always lower than prices of new vessels till 2004, since which, second-hand prices exceed new-building ones at most of the time, signifying a period of much speculation. These price series move more volatile during the period since 2003, compared to the previous period from 1990 to 2003. The summary statistics of logarithmic variables during sample period are presented in Table 5.10.

Results of all price series in the ship market in Table 5.10 show that during the sample period, the mean levels of new-building prices are higher than means of second-hand and scrap prices in all cases. Also, the means of prices for larger vessels are higher than those of smaller ones, as expected. Unconditional volatilities of all ship prices exhibit the mixed results. Prices for new-building vessels fluctuate less than both second-hand and scrap prices in all cases. While second-hand prices move less than scrap ones with the exception of the Panamax market. The results regarding volatilities are not consistent with those in Kavussanos and Alizadeh (2002b). There is usually a two-year time lag between the ordering and the delivery of a new vessel, while the time lag for a second-hand vessel is very limited. So many shipowners or investors switch to the second-hand market to hunt for suitable vessels during the unprecedented boom period of 2003 to 2007, and a panic selling of second-hand vessels occurred during the serious financial crisis in late 2008. Under these circumstances, second-hand prices move more sharply than newbuilding ones. These may explain why newbuilding prices fluctuate less than second-hand one during the sample period.

There is excess skewness for all ship price series in all cases, while only the second-hand prices show excess kurtosis. The J-B statistics reject the hypothesis of normality (skewness=0, kurtosis=3) for all ship prices. The Ljung-Box Q(20) and $Q^2(20)$ statistics reject the null hypothesis of non-autocorrelation and non heteroskedasticity in all price series. The augmented Dickey-Fuller and Philips Perron unit root tests display that all variables are log-first difference stationary, and all have a unit root on the log-levels representation.

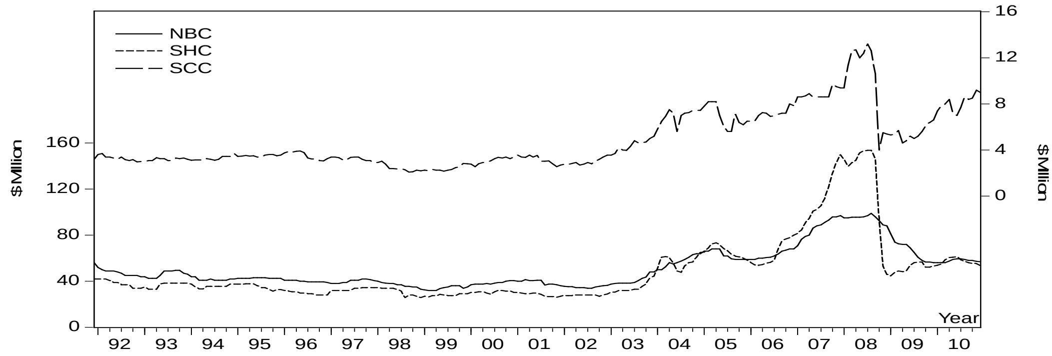

Figure 5.6: New-building prices(NBC), second-hand prices(SHC) and scrap prices(SCC) for Capesize vessels during Jan 1990 to Dec 2010.

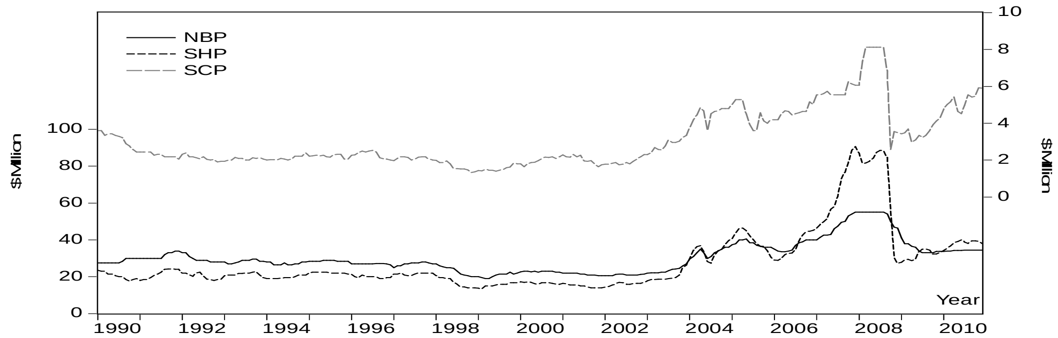

Figure 5.7: New-building prices(NBP), second-hand prices(SHP) and scrap prices(SCP) for Panamax vessels during Jan 1990 to Dec 2010

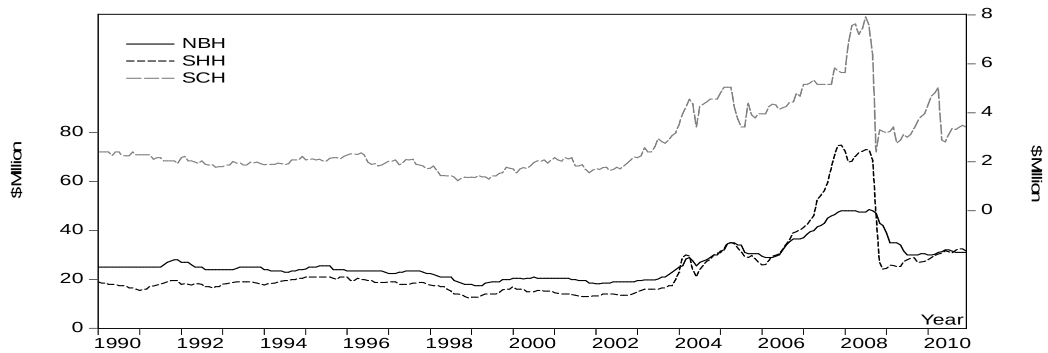

Figure 5.8: New-building prices(NBH), second-hand prices(SHH) and scrap prices(SCH) for Handymax vessels during Jan 1990 to Dec 2010.

Table 5.10: Descriptive statistics of logarithmic prices in the ship markets for three types of vessels

	N	Mean	Median	Std. Dev.	Skewness		Kurtosis		Jarque-Bera		Q(20)	$Q^2(20)$	ADF(lags)	PP	ADF(lags)	PP
													Lev	Lev	1^{st} diffs	1^{st} diffs
The Capesize market																
NBC	229	3.886	3.761	0.297	0.832	[0.00]	2.706	[0.46]	27.23	[0.00]	3518.6	3225.1	-1.21(2)	-1.22(9)	-6.77(1)	-11.56(9)
SHC	229	3.760	3.572	0.451	1.228	[0.00]	3.847	[0.00]	64.38	[0.00]	2882.3	2535.1	-1.97(1)	-1.58(5)	-8.45(0)	-8.20(1)
SCC	229	1.462	1.253	0.461	0.586	[0.00]	2.162	[0.06]	19.77	[0.00]	3214.4	2734.3	-1.19(0)	-1.11(2)	-15.75(0)	-15.75(1)
The Panamax market																
NBP	252	3.379	3.349	0.253	0.618	[0.00]	3.036	[0.83]	16.06	[0.00]	3319.3	3271.9	-1.23(1)	-1.43(9)	-10.22(0)	-10.79(7)
SHP	252	3.208	3.068	0.452	1.171	[0.00]	3.824	[0.00]	64.76	[0.00]	2980.3	2818.5	-1.81(1)	-1.55(6)	-9.54(0)	-9.47(3)
SCP	252	1.024	0.833	0.439	0.635	[0.00]	2.335	[0.16]	21.60	[0.00]	3192.6	2878.9	-1.31(0)	-1.24(3)	-16.47(0)	-16.47(3)
The Handymax market																
NBH	252	3.249	3.219	0.252	0.831	[0.00]	3.150	[0.42]	29.25	[0.00]	3491.7	3451.1	-1.08(1)	-1.28(9)	-10.16(0)	-10.92(8)
SHH	252	3.074	2.938	0.423	1.289	[0.00]	4.244	[0.00]	86.02	[0.00]	3018.5	2843.4	-1.86(1)	-1.49(4)	-9.34(0)	-8.96(9)
SCH	252	0.932	0.770	0.427	0.744	[0.00]	2.611	[0.24]	24.82	[0.00]	3296.2	2918.5	-1.26(0)	-1.15(2)	-16.74(0)	-16.74(1)

Notes:

- All prices are transformed into logarithmic.
- N is the number of observations
- Q(20) and $Q^2(20)$ are the Ljung and Box (1978) Q statistics on the first 20 lags of the sample autocorrelation function of the raw series and of the squared series; these tests are distributed as $\chi^2(20)$ .The critical values are 37.57 and 31.41 for the 1% and 5% levels, respectively.
- Lev and 1^{st} diffs refer to price series in log-levels and log-first differences, respectively. The 5% critical value for the ADF and PP tests is -2.869; the 1% critical value for the ADF and PP tests is -3.447.
- See other notes to Table 5.1.

5.3.2. Empirical results

The lagged exogenous variables are incorporated into a VAR-X model, because the inclusion of these exogenous variables is for the prediction of newbuilding prices. The lagged US dollar index, the lagged LIBOR and the lagged steel price are employed into a VAR model and it becomes a VAR-X model. Among three types of charter rates, three-year time charter rates are the one which can yield better values of SBC of a VAR-X model and coefficients of determination of the newbuilding ship equation in a VAR-X model for each ship size, therefore, three-year time charter rates are included into a VAR-X model. The standard errors of the estimated parameters are corrected for serial correlation and heteroskedasticity using the Newey-West(1987) method, and for heteroskedasticity only using White(1980) method. The lag length in each model is selected using the Schwarz Information Criterion. Results are reported in Table 5.11.

Findings from Table 5.11 could be explained from the perspective of newbuilding prices in this section. At first, changes of new-building prices are not influenced at the conventional significance levels by the lagged changes in second-hand prices and scrap prices for three types of vessels. This implies that the new-building market is primarily affected by the freight market and little influenced by the second-hand and the scrap markets.

Second, new-building prices have a significant effect on second-hand prices for Capesize and Panamax vessels with the exception of Handymax, where the coefficient of lagged newbuilding prices is not statistically significant. The new-building price usually poses a constraint on the upper limits of the second-hand vessel value. However, during the strong freight market, the second-hand ship price is more volatile and responds to the market information more quickly than the price of a new-building vessel and shipowners are willing to pay in excess of new-building prices to secure tonnage in time to meet the transport demand or make the speculative investment. New-building prices in this case seem not to influence second-hand ship prices significantly.

Third, changes in new-building prices seem not to have an impact on the movement of scrap prices with the exception of the Capesize market. This finding is consistent with the argument in Stopford (2009), who states that scrap prices are determined by the demolition tonnage, fundamentally affected by the freight market, and by the scrap metal price.

Finally, three-year time-charter rates have a significant positive impact on the determination of newbuilding ship prices, as expected for Panamax and Handymax, while for Capesize, three-year time-charter rates do not exhibit a significant impact on the newbuilding prices at the conventional significance levels.

Neither the lagged changes of the US dollar index, nor the lagged changes of the steel price in the newbuilding ship equation of the VAR-X model are observed to influence newbuilding prices significantly at the conventional levels. Results of the US dollar index and the steel price are consistent with those from the VECM-X models between newbuilding prices and charter rates. However, it is surprising to find that the LIBOR is statistically significant at the 5% significance level for three types of vessels and this implies that the lagged changes in the LIBOR have a significantly positive impact on newbuilding prices.

Table 5.11: Relationships between ship prices, charter rates and exogenous variables for each size

	Capesize				Panamax				Handymax			
	ΔNB_t	ΔSH_t	ΔSC_t	$\Delta TC3Y_t$	ΔNB_t	ΔSH_t	ΔSC_t	$\Delta TC3Y_t$	ΔNB_t	ΔSH_t	ΔSC_t	$\Delta TC3Y_t$
ΔNB_{t-1}	0.248** (3.75)	0.193* (1.728)	0.409 (1.61)	0.386 (1.29)	0.279** (4.596)	0.144* (1.675)	0.109 (0.464)	0.041 (0.16)	0.242** (3.80)	-0.081 (-0.68)	0.269 (0.938)	-0.053 (-0.283)
ΔSH_{t-1}	0.011 (0.317)	0.043 (0.795)	-0.221* (-1.715)	-0.030 (-0.19)	-0.005 (-0.182)	0.114** (2.05)	-0.187 (-1.588)	-0.168 (-1.429)	-0.005 (-0.139)	0.005 (0.075)	-0.024 (-0.138)	-0.224** (-2.094)
ΔSC_{t-1}	0.042* (1.957)	0.169** (4.584)	-0.189** (-2.53)	-0.028 (-0.289)	0.006 (0.327)	0.195** (5.443)	-0.199** (-2.635)	-0.069 (-0.862)	0.012 (0.694)	0.054 (1.645)	-0.176** (-2.26)	-0.014 (-0.266)
$\Delta TC3Y_{t-1}$	0.021 (1.184)	0.282** (8.155)	0.153** (2.17)	0.363** (4.16)	0.105** (6.063)	0.242** (8.717)	0.169** (2.89)	0.526** (7.251)	0.134** (4.292)	0.582** (9.858)	0.096 (0.688)	0.618** (6.687)
$\Delta usdx_{t-1}$	-0.061 (-0.722)	-0.531** (-3.694)	-0.769** (-2.496)	-1.60** (-4.19)	-0.038 (-0.519)	-0.168 (-1.27)	-0.348 (-1.242)	-0.694** (-2.295)	-0.022 (-0.32)	-0.105 (-0.826)	-0.756** (-2.50)	-0.373* (-1.87)
$\Delta libor_{t-1}$	0.071** (3.07)	0.021 (0.526)	-0.156* (-1.86)	-0.052 (-0.656)	0.040** (1.974)	0.011 (0.289)	-0.117 (-1.494)	-0.101 (-1.199)	0.063** (3.33)	0.012 (0.358)	-0.203** (-2.364)	-0.054 (-0.958)
$\Delta steel_{t-1}$	0.058 (1.518)	-0.010 (-0.173)	-0.079 (-0.618)	0.075 (0.473)	0.024 (0.761)	-0.024 (-0.409)	-0.077 (-0.629)	0.078 (0.592)	0.022 (0.714)	0.039 (0.672)	-0.246* (-1.79)	-0.014 (-0.153)
$Q(20)$	23.81 [0.25]	22.32 [0.324]	16.03 [0.64]	34.63 [0.03]	19.685 [0.48]	36.72 [0.01]	20.93 [0.40]	39.03 [0.01]	25.10 [0.24]	14.45 [0.81]	25.57 [0.180]	19.88 [0.465]
$Q^2(20)$	24.08 [0.24]	1.77 [1.00]	2.53 [1.00]	53.86 [0.00]	34.55 [0.02]	12.95 [0.88]	3.75 [1.00]	64.25 [0.00]	28.21 [0.10]	9.75 [0.97]	12.759 [0.88]	2.40 [0.99]
$\overline{R}^2$	0.19	0.59	0.055	0.22	0.317	0.640	0.104	0.235	0.311	0.559	0.059	0.27

Notes:

- All variables are transformed in natural logarithms
- ΔNB_t means the first difference of logarithmic new-building ship prices, ΔSH_t the first difference of logarithmic second-hand prices, ΔSC_t the first difference of logarithmic scrap prices. $\Delta usdx_t$ the first difference of logarithmic US Dollar index; $\Delta libor_t$ the first difference of the logarithmic LIBOR; $\Delta steel_t$ means the logarithmic first difference of the steel price.
- ! denotes that the sample period for the Capesize vessels ranges from Jan, 1991 to Dec, 2010.
- ** and * indicate significance at the 5% and 10% levels, respectively
- Figures in braces (.) indicate t-statistics
- $Q(20)$ and $Q^2(20)$ are the Ljung and Box (1978) tests for 20th order serial correlation and heteroskedasticity in the standardized residuals and in the standardized squared residuals, respectively.

5.4. Forecasts

Based on the analysis above, forecasts are made for newbuilding prices for all ship types. The US dollar index and the steel price are found to have no significant impact on newbuilding prices, they are consequently not incorporated into time series models. While the LIBOR is observed to be significant in some cases of VEC models and in VAR models described above, it is then incorporated into various time series models to check its impact on the forecasting performance. Forecasting models employed here include the random walk, ARMA, ARMA-X, VAR, VAR-X, VECM and VECM-X models.

Charter rates in this chapter include spot rates, one-year time charter rates and three-year time charter rates. These three types of charter rates will not be all incorporated and discussed in the forecasting models, one of which will be selected into the VAR and VECM models to take as an instance. The Schwarz Bayesian Information Criterion (SBC; Schwarz, 1978) and the coefficient of determination ($\overline{R}^2$) are utilized to choose charter rates, which can reduce the value of SBC and improve the value of $\overline{R}^2$.

For the VAR model, the VAR model with three-year time-charter rates seems to be the best one for three types of vessels. Hence, the VAR model includes new-building prices, second-hand ship prices, scrap prices and three-year time-charter rates for Capesize, Panamax and Handymax vessels.

For the VECM model, it is constructed based on the pair between new-building ship prices and three-year time-charter rates for Capesize vessels with the lower value of the Schwarz information criterion, and it is constructed based on the pair between new-building ship prices and three-year time-charter rates for Panamax and Handymax vessels with better values of the determination and the Schwarz criterion.

The sample period for Capesize is from Dec 1991 to Dec 2010, while that for the other two types of bulk vessels runs from Jan 1990 to Dec 2010. For estimation and forecast purposes, the data are split into an in-sample estimation set and an out-of sample forecast set. The various models are estimated over the whole period from Jan 1990 to June 2009 for Panamax and Handymax, and over the period from Dec 1991 to June 2009 for Capesize. The period from July 2009 to Dec 2010, is then utilized to evaluate independent out-of-sample N-period ahead of forecasts. Results of various forecasting models over the estimation period are reported in Tables 5.12-5.14.

These alternative univariate and multivariate models, estimated over the initial estimation period, are used to generate independent forecasts of new-building ship prices up to three months ahead. This method yields 18, 17 and 16 independent non-overlapping forecasts for one step, two steps and three-steps ahead, respectively. The forecasting capabilities of various econometric methods are assessed for three types of vessels by using the following criteria including the root mean square error metric (RMSE), mean absolute error (MAE) and Theil's inequality coefficient (Theil's). The best forecasting model would be the one that produces the lowest RMSE, MAE, and Theil's. The forecasting performance of various models can be found in Table 5.15.

Table 5.12: Estimates of forecasting models for Capesize vessels during the period Jan 1990 to Jun 2009

	ARMA	ARMAX		VECM		VECM-X			VAR				VAR-X			
	ΔNBC_t	ΔNBC_t		ΔNBC_t	$\Delta TC3Y_t$	ΔNBC_t	$\Delta TC3Y_t$		ΔNBC_t	ΔSHC_t	ΔSCC_t	$\Delta TC3Y_t$	ΔNBC_t	ΔSHC_t	ΔSCC_t	$\Delta TC3Y_t$
ΔNBC_{t-1}	0.239** (3.53)	0.215** (3.168)	Z_{t-1}	-0.049** (-4.73)	0.239* (1.78)	-0.046** (-4.27)	0.244* (1.91)	ΔNBC_{t-1}	0.252** (3.709)	0.155 (1.32)	0.409* (1.652)	0.322 (1.100)	0.240** (3.51)	0.162 (1.37)	0.444* (1.79)	0.359 (1.122)
ΔNBC_{t-2}	0.215** (3.168)	0.203** (2.992)	ΔNBC_{t-1}	0.190** (2.931)	0.825* (1.908)	0.188** (2.89)	0.821* (1.84)	ΔSHC_{t-1}	0.047 (1.295)	0.079 (1.25)	-0.258** (1.95)	0.048 (0.283)	0.028 (0.772)	0.088 (1.37)	-0.213 (-1.57)	0.098 (0.558)
$\Delta libor_{t-1}$		0.047* (1.809)	$\Delta TC3Y_{t-1}$	0.018 (1.25)	0.503** (3.485)	0.019 (1.35)	0.507** (3.35)	ΔSCC_{t-1}	0.029 (1.357)	0.187** (4.997)	-0.166* (-2.108)	0.028 (0.281)	0.044* (1.96)	0.179** (4.61)	-0.201** (-2.458)	-0.009 (-0.091)
			$\Delta libor_{t-1}$			0.017 (1.02)	0.04 (0.56)	$\Delta TC3Y_{t-1}$	0.014 (1.136)	0.283** (8.217)	0.086 (1.306)	0.371** (3.956)	0.017 (1.39)	0.281** (8.15)	0.187** (2.458)	0.363** (3.876)
								$\Delta libor_{t-1}$					0.063** (2.315)	-0.030 (-0.637)	-0.152 (-1.53)	-0.165 (-1.29)
$\bar{R}^2$	0.128	0.137	$\bar{R}^2$	0.214	0.256	0.211	0.253	$\bar{R}^2$	0.137	0.586	0.033	0.161	0.156	0.583	0.039	0.163
AIC	-4.431	-4.437	AIC	-4.562	-1.511	-4.554	-1.502	AIC	-4.464	-3.388	-1.894	-1.386	-4.481	-3.381	-1.896	-1.384
SC	-4.398	-4.389	SC	-4.514	-1.463	-4.490	-1.438	SC	-4.401	-3.324	-1.830	-1.322	-4.401	-3.300	-1.816	-1.304
$Q(20)$	28.74 [0.09]	29.99 [0.07]	$Q(20)$	25.11 [0.20]	27.99 [0.11]	24.92 [0.20]	27.98 [0.11]	$Q(20)$	26.57 [0.16]	13.82 [0.83]	10.41 [0.96]	33.67 [0.04]	25.95 [0.167]	14.60 [0.799]	9.33 [0.97]	32.33 [0.05]
$Q^2(20)$	18.28 [0.57]	19.32 [0.50]	$Q^2(20)$	14.43 [0.81]	64.22 [0.00]	14.91 [0.78]	63.69 [0.00]	$Q^2(20)$	20.98 [0.39]	1.27 [1.00]	2.42 [1.00]	57.35 [0.00]	20.92 [0.42]	1.23 [1.00]	2.23 [1.00]	57.32 [0.00]

Notes:

- All the series are measured in logarithmic first differences. ΔNBC_t, ΔSHC_t, ΔSCC_t, $\Delta TC1Y_t$ and $\Delta TC3Y_t$ mean logarithmic first differences of new-building, second-hand prices, scrap prices, one-year and three-year timecharter prices for Capesize
- Figures in parenthesis (·) means t -statistics, adjusted using the White(1980) heteroskedasticity consistent variance-covariance matrix. * and ** denote significance at the 10% and 5% levels, respectively. Figures in square brackets [·] indicate exact significance levels
- Q(20) and $Q^2(20)$ are the Ljung and Box (1978) Q statistics on the first 20 lags of the sample autocorrelation function of the raw series and of the squared series; these tests are distributed as $\chi^2(20)$ .The critical values are 37.56 and 31.41 for the 1% and 5% levels, respectively

Table 5.13: Estimates of forecasting models for Panamax vessels during the period Jan 1990 to Jun 2009

	ARMA	ARMAX		VECM		VECM-X			VAR				VAR-X			
	ΔNBP_t	ΔNBP_t		ΔNBP_t	$\Delta TC3Y_t$	ΔNBP_t	$\Delta TC3Y_t$		ΔNBP_t	ΔSHP_t	ΔSCP_t	$\Delta TC3Y_t$	ΔNBP_t	ΔSHP_t	ΔSCP_t	$\Delta TC3Y_t$
ΔNBP_{t-1}	0.405** (6.669)	0.393** (6.52)	Z_{t-1}	-0.023** (-3.23)	0.125** (4.288)	-0.021** (-3.02)	0.118** (4.13)	ΔNBP_t	0.291** (4.66)	0.212* (1.96)	0.148 (0.654)	0.081 (0.236)	0.286** (4.64)	0.217** (2.02)	0.158 (0.69)	0.094 (0.37)
$\Delta libor_{t-1}$		0.042** (1.97)	ΔNBP_{t-1}	0.236** (4.077)	0.221 (0.945)	0.229** (3.967)	0.241 (1.03)	ΔSHP_{t-1}	0.008 (0.264)	0.151** (2.96)	-0.282** (-2.62)	-0.189 (-1.05)	-0.008 (-0.26)	0.170** (3.24)	-0.249** (-2.25)	-0.144 (-1.16)
			$\Delta TC3Y_{t-1}$	0.096** (6.493)	0.559** (9.368)	0.098** (6.708)	0.552** (9.24)	ΔSCP_{t-1}	-0.006 (-0.328)	0.209** (6.19)	-0.242** (-3.407)	-0.047 (-0.417)	0.005 (0.27)	0.195** (5.59)	-0.266** (-3.62)	-0.080 (-0.97)
			$\Delta libor_{t-1}$			0.044** (2.02)	-0.117 (-1.31)	$\Delta TC3Y_{t-1}$	0.109** (5.882)	0.318** (10.00)	0.373** (5.571)	0.558** (2.682)	0.111** (6.10)	0.316** (9.95)	0.369** (5.51)	0.552** (7.35)
								$\Delta libor_{t-1}$					0.054** (2.28)	-0.065 (-1.57)	-0.109 (-1.25)	-0.152 (-1.55)
$\bar{R}^2$	0.160	0.169	$\bar{R}^2$	0.349	0.282	0.357	0.284	$\bar{R}^2$	0.317	0.646	0.112	0.231	0.329	0.648	0.114	0.236
AIC	-4.44	-4.452	AIC	-4.695	-1.897	-4.704	-1.896	AIC	-4.643	-3.545	-2.058	-1.824	-4.657	-3.547	-2.056	-1.826
SC	-4.42	-4.422	SC	-4.65	-1.852	-4.644	-1.895	SC	-4.584	-3.486	-1.999	-1.765	-4.583	-3.473	-1.982	-1.752
$Q(20)$	23.73 [0.25]	23.46 [0.27]	$Q(20)$	9.98 [0.97]	42.11 [0.00]	9.06 [0.98]	41.68 [0.01]	$Q(20)$	10.12 [0.96]	34.10 [0.03]	16.78 [0.67]	36.53 [0.02]	9.89 [0.97]	33.47 [0.05]	15.13 [0.77]	37.81 [0.01]
$Q^2(20)$	19.19 [0.48]	23.17 [0.28]	$Q^2(20)$	16.52 [0.68]	77.63 [0.00]	21.43 [0.37]	74.89 [0.00]	$Q^2(20)$	13.73 [0.84]	30.55 [0.06]	7.47 [0.99]	67.28 [0.00]	14.86 [0.83]	28.61 [0.10]	6.85 [0.99]	61.49 [0.00]

Notes: All the series are measured in logarithmic first differences. ΔNBP_t, ΔSHP_t, ΔSCP_t, $\Delta TC1Y_t$ and $\Delta TC3Y_t$ mean logarithmic first differences of new-building, second-hand prices, scrap prices, one-year and three-year timecharter prices for Panamax; see other notes to Table 5.12.

Table 5.14: Estimates of forecasting models for Handymax vessels during the period Jan 1990 to Jun 2009

	ARMA	ARMAX		VECM		VECM-X			VAR				VAR-X			
	ΔNBH_t	ΔNBH_t		ΔNBH_t	$\Delta TC3Y_t$	ΔNBH_t	$\Delta TC3Y_t$		ΔNBH_t	ΔSHH_t	ΔSCH_t	$\Delta TC3Y_t$	ΔNBH_t	ΔSHH_t	ΔSCH_t	$\Delta TC3Y_t$
ΔNBH_{t-1}	0.399** (6.493)	0.375** (6.112)	Z_{t-1}	-0.059** (-4.981)	0.100** (2.792)	-0.052** (-4.56)	0.090** (2.54)	ΔNBH_{t-1}	0.255** (3.88)	-0.079 (-0.656)	0.075 (0.273)	-0.096 (-0.497)	0.241** (3.74)	-0.077 (-0.63)	0.106 (0.38)	-0.076 (-0.39)
$\Delta libor_{t-1}$		0.056** (2.469)	ΔNBH_{t-1}	0.17** (2.829)	-0.085 (-0.463)	0.152** (2.538)	-0.052 (-0.283)	ΔSHH_{t-1}	0.025 (0.63)	0.022 (0.315)	-0.097 (-0.60)	-0.231** (-2.04)	0.000 (0.002)	0.027 (0.37)	-0.043 (-0.25)	-0.197* (-1.71)
			$\Delta TC3Y_{t-1}$	0.104** (5.098)	0.580** (9.329)	0.111** (5.50)	0.568** (9.11)	ΔSCH_{t-1}	0.002 (0.08)	0.072** (2.03)	-0.174** (-2.155)	-0.013 (-0.227)	0.017 (0.88)	0.069* (1.88)	-0.209** (-2.52)	-0.035 (-0.60)
			$\Delta libor_{t-1}$			0.053** (2.64)	-0.093 (-1.51)	$\Delta TC3Y_{t-1}$	0.122** (3.62)	0.567** (9.18)	0.232** (1.645)	0.657** (6.685)	0.129** (3.89)	0.566** (9.12)	0.216 (1.54)	0.647** (6.59)
								$\Delta libor_{t-1}$					0.072** (3.28)	-0.014 (-0.32)	-0.162* (-1.72)	-0.102** (6.59)
$\bar{R}^2$	0.151	0.169	$\bar{R}^2$	0.352	0.272	0.367	0.276	$\bar{R}^2$	0.280	0.570	0.009	0.258	0.310	0.568	0.018	0.262
AIC	-4.633	-4.651	AIC	-4.894	-2.663	-4.914	-2.664	AIC	-4.786	-3.569	-1.922	-2.640	-4.823	-3.561	-1.927	-2.642
SC	-4.619	-4.621	SC	-4.850	-2.619	-4.855	-2.605	SC	-4.727	-3.510	-1.863	-2.581	-4.749	-3.487	-1.853	-2.568
$Q(20)$	20.78 [0.41]	20.96 [0.40]	$Q(20)$	20.55 [0.42]	19.674 [0.478]	18.50 [0.55]	18.32 [0.56]	$Q(20)$	21.51 [0.37]	16.18 [0.70]	12.77 [0.88]	18.28 [0.28]	22.34 [0.32]	15.79 [0.73]	11.86 [0.92]	16.75 [0.67]
$Q^2(20)$	38.47 [0.01]	38.62 [0.04]	$Q^2(20)$	18.92 [0.53]	3.18 [1.00]	17.90 [0.57]	3.09 [1.00]	$Q^2(20)$	28.09 [0.11]	6.58 [0.99]	3.34 [0.99]	2.57 [1.00]	28.67 [0.09]	6.48 [0.99]	3.06 [0.99]	2.64 [1.00]

Notes: All the series are measured in logarithmic first differences. ΔNBH_t, ΔSHH_t, ΔSCH_t, ΔSHP_t and $\Delta TC3Y_t$ mean logarithmic first differences of new-building, second-hand prices, scrap prices, one-year and three-year timecharter prices for Handymax; see other notes to Table 5.12.

Table 5.15: The forecasting performance of various forecasting models in three markets

Panel A: Out-of-sample forecasts during the forecast period 2009.07-2010.12 for Capesize vessels												
	One-step ahead				*Two-step ahead*				*Three-step ahead*			
Model	N	RMSE	MAE	Theil's	N	RMSE	MAE	Theil's	N	RMSE	MAE	Theil's
RM	18	0.0273	0.0183	0.0034	17	0.0499	0.034	0.0061	16	0.0662	0.0463	0.0081
ARMA	18	0.0190	0.0131	0.0023	17	0.0318	0.0222	0.0039	16	0.0387	0.0272	0.0048
ARMA-X	18	0.0177	0.0138	0.0022								
VECM	18	0.0199	0.0147	0.0024	17	0.0386	0.0252	0.0048	16	0.0532	0.0359	0.0066
VECM-X	18	0.0189	0.0137	0.0023								
VAR	18	0.0221	0.0155	0.0027	17	0.0373	0.0238	0.0046	16	0.0473	0.0315	0.0058
VAR-X	18	0.0185	0.0135	0.0023								
Panel B: Out-of-sample forecasts during the forecast period 2009.07-2010.12 for Panamax vessels												
	One-step ahead				*Two-step ahead*				*Three-step ahead*			
Model	N	RMSE	MAE	Theil's	N	RMSE	MAE	Theil's	N	RMSE	MAE	Theil's
RM	18	0.0093	0.0046	0.0013	17	0.0111	0.0071	0.0016	16	0.0128	0.0094	0.0018
ARMA	18	0.0073	0.0045	0.0010	17	0.0082	0.0059	0.0012	16	0.0090	0.0066	0.0013
ARMA-X	18	0.0105	0.0077	0.0015								
VECM	18	0.0136	0.0107	0.0019	17	0.0219	0.0179	0.0031	16	0.0267	0.0222	0.0038
VECM-X	18	0.0169	0.0136	0.0024								
VAR	18	0.0113	0.0095	0.0016	17	0.0176	0.0149	0.0025	16	0.0206	0.0180	0.0029
VAR-X	18	0.0138	0.0114	0.0019								
Panel C: Out-of-sample forecasts during the forecast period 2009.07-2010.12 for Handymax vessels												
	One-step ahead				*Two-step ahead*				*Three-step ahead*			
Model	N	RMSE	MAE	Theil's	N	RMSE	MAE	Theil's	N	RMSE	MAE	Theil's
RM	18	0.0163	0.0104	0.0024	17	0.0228	0.0185	0.0033	16	0.0281	0.0227	0.0041
ARMA	18	0.0124	0.0098	0.0018	17	0.0166	0.0138	0.0024	16	0.0201	0.0158	0.0029
ARMA-X	18	0.0133	0.0114	0.0020								
VECM	18	0.0134	0.0098	0.0019	17	0.0203	0.0171	0.0030	16	0.0258	0.0234	0.0038
VECM-X	18	0.0128	0.0103	0.0018								
VAR	18	0.0141	0.0100	0.0021	17	0.0216	0.0185	0.0032	16	0.0267	0.0227	0.0039
VAR-X	18	0.0138	0.0121	0.0020								

Notes: RMSE is the conventional root mean square error metric; MAE denotes mean absolute error and Theil's is the Theil's inequality coefficient.

Findings regarding the forecasting performance of various models can be summed up as follows. Results indicate that the ARMA outperforms all the other models for all forecasting horizons in three markets. The incorporation of second-hand ship prices and scrap prices does not provide additional information in the prediction of newbuilding ship prices, because parameters of second-hand ship prices and scrap prices are insignificant in the forecasting models. While it also finds that the inclusion of period charter rates in the VAR model and the long-run relationship between newbuilding ship prices and period charter rates in the VECM model seem not to be helpful in improving the forecasting performance of newbuilding ship prices during the forecasting period.

The disadvantage of the extended VAR and VEC models is that it is designed only for forecasts of one step ahead. If the VAR-X and VECM-X models are used to go further to predict prices two steps more ahead, the forecasts of exogenous variables should be known, which are difficult to get.

For Capesize and Handymax markets, the random walk model performs the worst compared to other time series models, while it is not the case for Panamax, where the random walk model performs better than the VECM and VAR models.

With regards to the economic indicator of the LIBOR, results indicate that this indicator seems to improving slightly the forecasting performance of various time series models for Capesize. For Panamax, the inclusion of the LIBOR does not help in the prediction of newbuilding prices, and for Handymax the result is mixed. As a consequence, there is no robust conclusion which can be drawn from the mixed results that the extended time series models with the LIBOR perform better in the prediction of newbuilding prices for three types of dry bulk vessels.

Findings confirm that the newbuilding ship market is a relatively separate one, and can be influenced by not only the freight market, but also some factors out of the shipping market, such as government subsidies, credit policies and investors' heterogeneous shipbuilding motives. The newbuilding ship market, therefore, does not respond to the shipping freight market simultaneously and there would be a time lag for the information in the freight market to be fully incorporated into the shipbuilding market. It can be seen that sometimes newbuilding prices for benchmark vessels may keep unchanged for several months, during which changes in the freight market seem not to have an instant impact on the shipbuilding market.

5.5. Simulation-based optimization of ship design for newbuilding vessels[5]

Not only the price of a newbuilding vessel, but also the main specifications of a new vessel, are always the most concerned issues for shipowners. Although shipyards sell standard vessels, most ships are designed to buyers' specification.The optimization of ship design is, therefore, always one of the most important research subjects in the newbuilding ship market. Within ship design, three main stakeholders are involved, namely, the ship-owner, the shipbuilder and the first time-charterer. For the ship-owner, he defines the main specifications in close cooperation with the time charterer and pays for the ship. The detailed design of the hull, machinery and construction are left for the shipbuilder and subcontractor. Because ship owners always keep in mind the economical advantage of a ship, they usually make their decisions with ship design based on economic grounds. In other words, the optimal solution of ship design for ship owners is the one that can either minimize operating costs or maximize the potential earnings during ship operational life.

The subject of optimal ship design for ship owners has been investigated by many researchers. A considerable number of maritime economists focus on the determination of optimal ship size or speed. Examples are Jansson and Shneerson (1982, 1987), Garrod and Miklirs (1985), Talley and Pope (1988), Lim (1994), Cullinane and Khanna (1999, 2000), Sys et al (2008) among others. These studies give an

[5] Section 5.5 is based on the paper 'Simulation-based optimization of ship design for dry bulk vessels', published on *Journal of Maritime Economics and Logistics*, 2011.

insight into the optimization of ship size or ship speed, from which it can be concluded that one cannot make general statements about optimal ship size and speed. The optimization process is actually related with the ship service requirements. However, the optimization approaches in these studies are used for investigating the optimal ship size or speed without going further to the main technical design parameters.

This section proposes an integrated scheme of technical, logistical and economic analysis for ship owners to optimize the ship design, particularly in determining the main technical specifications, including main dimensions, deadweight, design and economical speed, and the power requirement at the conceptual design stage. As literature indicates, the optimization of ship design has to be based on the specific service requirements and cannot be analyzed without reference to the ship operations, our study focuses on the design of ore carriers in the dry bulk market, utilized to serve the transportation of iron ore imported from Brazil to China. Specifically, we assume a new company is set up by a steel mill, and a shipping company, to be jointly in charge of the iron ore transportation with new ships to be designed and built. In this case, questions like: what is the carrying capacity of a ship, what is the maximum speed of a ship, how many ships are required, etc. should be the concern of both the steel mill and the ship-owner.

On the whole, there are three main systems in the whole optimization process: the ship design model; the shipping system and the shore logistics system. The technical and economical variables in ship design, the economic variables based on ship’s practical operation in the shipping system and other variables in the shore logistics system, are all interconnected. Any changes to major technical variables can result in changes to others and vice versa. The economic objectives can be achieved subject to some constraints through optimization iterations among three parts. The optimization results are obtained by Monte Carlo simulation within the Spreadsheet based Crystal Ball software by embedding Solver to deal with the design solution.

The main differences of our research with previous studies rest with three aspects. Firstly, apart from required ship size and speed, other main technical specifications of the ship are determined during the optimization process. Secondly, the shore logistics plan is incorporated into the whole optimization process, and Monte Carlo simulation is needed to vary extra sea time and port time in the shipping system, as well as monthly iron ore demand of the steel mill in the shore logistics plan, which significantly influences the ship design as well. The incorporation of a logistics scheme into the whole process increases the complexity of the design option. Thirdly, ship design schemes can be tailored to meet various economic objectives considered by different parties.

5.5.1. The optimization model descriptions

The optimization model in this section attempts to design a series of ships with different deadweight, having the optimum main technical specifications and to obtain the optimum logistic plan for each of these designs.

The ships are used to serve the transportation of a certain amount of iron ore. The logistic cost per unit is utilized as the objective of the optimization problem. In this section, the minimum logistic cost per ton must be obtained to guarantee that the optimum ship design and logistic plan are achieved. In other words the collection of optimal designs with varying deadweight and shore logistical plans enables the user to choose the optimal deadweight based on the cost per ton.

Descriptions of the three systems

There are three main systems in the whole optimization process, namely the design model, the shipping system and the shore logistics system. The technical variables in the ship design system, such as but not limited to the deadweight, the design speed and the depth; the economic variables based on ship’s practical operation in the shipping system, such as the shipping cost and the logistic cost; as well as other variables in the shore logistics system, are all interconnected. Any changes to major technical variables can result in changes to others and vice versa. The economic objectives can be achieved subject to some constraints through optimization iterations between three parts.

Specifically, the design model covers the ship data, machinery data, power data and some economic data, as illustrated in Table 5.16. The specific design model focuses on the determination of the main technical parameters of the ship, main dimensions, hull fullness coefficients, economical speeds and the required power, when given the value of deadweight. The design parameters need to fall within specified ranges. A minimum and a maximum value are set on the constrained parameters in order to limit the solution space towards the known space of the optimal solution, consequently preventing failures or saving time in the calculations.

Table 5.16: Components of the design model

Input	*Constrained parameters*	*Output*
♦ Design deadweight ♦ T max ♦ Fuel use in gram/kWh ♦ Rpm propeller and diesel engine ♦ Design speed ♦ Economic data	♦ Lwl/D ♦ Lwl/B ♦ B/T ♦ T ♦ Cb ♦ Displacement ♦ V	♦ Loa, Lwl, B, D, T, Cb ♦ Economical speed laden and ballast. ♦ Fuel consumption per day laden and ballast. ♦ Installed power ♦ Lightship ♦ Costs per ton-mile

In Table 5.16, Loa means the length overall of the vessel, Lwl the length on the waterline of the vessel, D depth of the vessel, B breadth of the vessel, T draft, Cb block coefficient and V speed of the vessel.

The shipping system covers the voyage data, ship data, port data and their economic data, as illustrated in Table 5.17. All of these data are necessary in calculating the voyage cost, the operation cost and the capital cost of a vessel. Ship data are imported from the design model. For instance, the fuel consumption per day is calculated based on the specific fuel consumption and the required power at the economical speed, all of which originate from the design model. Additionally, the new-building price is estimated based on the building cost plus a certain percentage of market dependent profits. In this section, the profit level is estimated as the average level of profits during the period from 2000 to 2009, covering both the strong and the weak market conditions, based on new-building prices of Clarksons Intelligent Network (2010) and building costs from our design model. Any changes to the ship data will result in changes to the shipping costs.

The shore logistic system covers the demand data, inventory data, order data and other economic data, utilized to calculate the inventory costs, as shown in Table 5.18. Total inventory costs typically include holding, ordering, shortage, and purchasing costs. In a continuous review system, managers continuously monitor the inventory position. Whenever the inventory position falls at or below a level q, called the reorder point, the manager orders Q units, called the order quantity. When you receive the order after the lead-time, the inventory level jumps from zero to Q, and the cycle repeats.

Order quantity in the shore logistic system is equal to one shipment of a vessel, determined by the cargo stowage factor and ship deadweight in the design model. Lead time here refers to the total round voyage time, determined by the sailing time at sea and the service time at both loading and discharging terminals, which come from the shipping system. In this section, the round trip time, not the laden voyage time, is denoted as lead time, because it’s the total time spent for one shipment. In this way, three systems are all connected to each other.

Table 5.17: Components of the shipping system

Voyage Data	Voyage Distance	laden and ballast	mile
	Cargo quantity		ton
	Sea Time	laden days, ballast days plus sea margin	d
	Port time	Loading and discharging time plus port margin	d
	Canal Time	canal days if any	d
Ship Data	Annual operation days		day
	Deadweight		ton
	Operating Speed	Laden speed and Ballast speed	knot
	Consumption at sea	IFO at sea(l) and at sea(b)	ton
		Diesel oil at sea	ton
	Consumption at port	IFO and MDO consumption	ton
	Crew number		
Port data	Cargo Handling rate	Loading and discharging rate	
	Harbour Cost per unit		$/ton
Other data	Bunker price	prices for IFO and MDO	$/ton
	Interest rate		
	Loan period		
	Depreciation year		
Number of Shipments per vessel per year			
Annual voyage cost per vessel			$
Annual operating cost per vessel			$
Annual capital cost per vessel			$
Annual total shipping costs			$
Shipping Costs per unit			$/ton

Table 5.18: Components of the logistics system

Demand data	annual steel production capacity	ton
	maximal iron ore demand per year	ton
	weekly iron ore demand	ton
Order data	order quantity	ton
	reorder point	ton
	unit order cost	$
Inventory data	Initial inventory	ton
	weekly holding quantity	ton
	weekly lost sales	ton
	unit storage cost	$/ton
Lead time	actual round voyage time	days
Beginning inventory and position each week		ton
Ending inventory and position each week		ton
Order cost		$
Hold cost		$
Short cost		$
Total cost		$

The optimization structure

The Crystal Ball software is employed by embedding the Microsoft Excel Solver to deal with the optimization problem. The Microsoft Excel Solver is intended to acquire the optimum ship design values, by changing a set of design parameters, subject to certain constraints, to minimize the objective function in the design model based on the economic calculations. The Solver uses the Generalised Reduced Gradient (GRG) method, as implemented in an enhanced version of GRG2 code in Lasdon and Waren (1978). The GRG2 code has been proven in use over many years as one of the most robust and reliable approaches to solving difficult nonlinear problems. The Solver not only finds a feasible solution to a problem, but also locates the optimal solution, given a set of cells (representing decision variables) that it can change, a set of constraints that must be satisfied, and one cell (denoting the objective function) that must be optimized for the minimum, maximum, or on-the-target.

As mentioned above, the optimization process incorporates the shore logistic system in our research. Typically, the objective in the shore logistic system is to minimize total inventory costs. In the shore logistic system, demand is usually uncertain, and the lead time can also vary. To avoid shortages, managers often maintain a safety stock. In such situations, it is not clear what order quantities and reorder points will minimize the expected total inventory cost. Simulation, therefore, can be used to address this question.

Before simulation, probability distributions are created to describe the uncertainty of specific input variables, referred to in Crystal Ball as ‘assumptions’. Apart from ‘assumptions’, ‘decision variables’, values to be set by the user, and “forecast” containing formulas and equations that we want to analyze after a simulation, should also be defined before simulation. When you run a simulation, Crystal Ball generates a random number for each assumption and places the new value in the cell. The Excel then recalculates the model.

In our research, iron ore demand, shipping time at sea and service time at terminals are assumptions. The Deadweight of a vessel in the design model and reorder level in the shore logistic system are specified as ‘decision variables’. The logistics cost per ton is defined as “forecast”, which must be minimized.

We assume the iron ore demand D, fluctuates about a mean of the expected demand, which follows a Gaussian distribution. In view of some unexpected sea state and wind conditions, we describe the shipping time at sea by a Gamma distribution function with density

$$T_s = e^{-t/\theta} \frac{t^{k-1}}{\theta^k \Gamma(k)} \tag{5.1}$$

Where t is the random variable; θ a shape parameter and k the scale parameter. Both k and θ are positive values and k in the research is a positive integer.

At terminals, there are always some unexpected conditions, which create the possibility of the delay in berthing vessels and the breakdown or failure that affects ordinary operations. In case of delays due to port congestions or decelerations of operations, port time at loading and discharging terminals must be varied. Hence, service time at terminals can be represented by a Gamma distribution, as used in Assumma and Vitetta (2006).

$$T_p = T_{pd} + T_{ps} \tag{5.2}$$

where T_p is the total service time at terminals; T_{pd} is the deterministic loading or discharging time under ordinary conditions; T_{ps} is the stochastic time calculated under unexpected conditions, represented by a Gamma distribution function.

Since assumptions, decision variables and forecast variables have been determined, Crystal Ball is used to perform a Monte Carlo simulation on the spreadsheet. Examples of running a Monte Carlos simulation in

Crystal Ball can be seen in Charnes (2007) and Evans (2007) among others. Glasserman (2004) indicates that a Monte Carlo simulation is a widely used technique for iteratively evaluating a deterministic model using sets of random numbers as inputs, generated according to probabilities assumed to be associated with a source of uncertainty, such as iron ore demand, shipping time at sea and service time at terminals in the research. Outputs associated with these random variables are then analyzed to determine the likely results and the associated risk.

For each optimization, a new value is selected within the defined range of decision variables. Because the Microsoft Excel Solver is embedded into the design model by creating an Excel macro to invoke it before every simulation trial, the Solver is at first invoked to run and produce the optimum design, which will be exported into the shipping system and shore logistic system. Afterwards, a Crystal Ball simulation (e.g., 1000 trials, the number of trials is chosen based on the standard error of the mean of the forecast values) starts to run. The mean value of the forecast will be saved after simulation and be checked to see if the requirement is met and so is considered feasible. If the requirement is not met, the solution is considered infeasible. The Crystal Ball runs another simulation on a new set of decision variables and repeats this process, constantly searching for the minimum logistics cost per ton until it either works through every possible solution or reaches the end of the set running time. Figure 5.9 shows the general structure of this optimization problem.

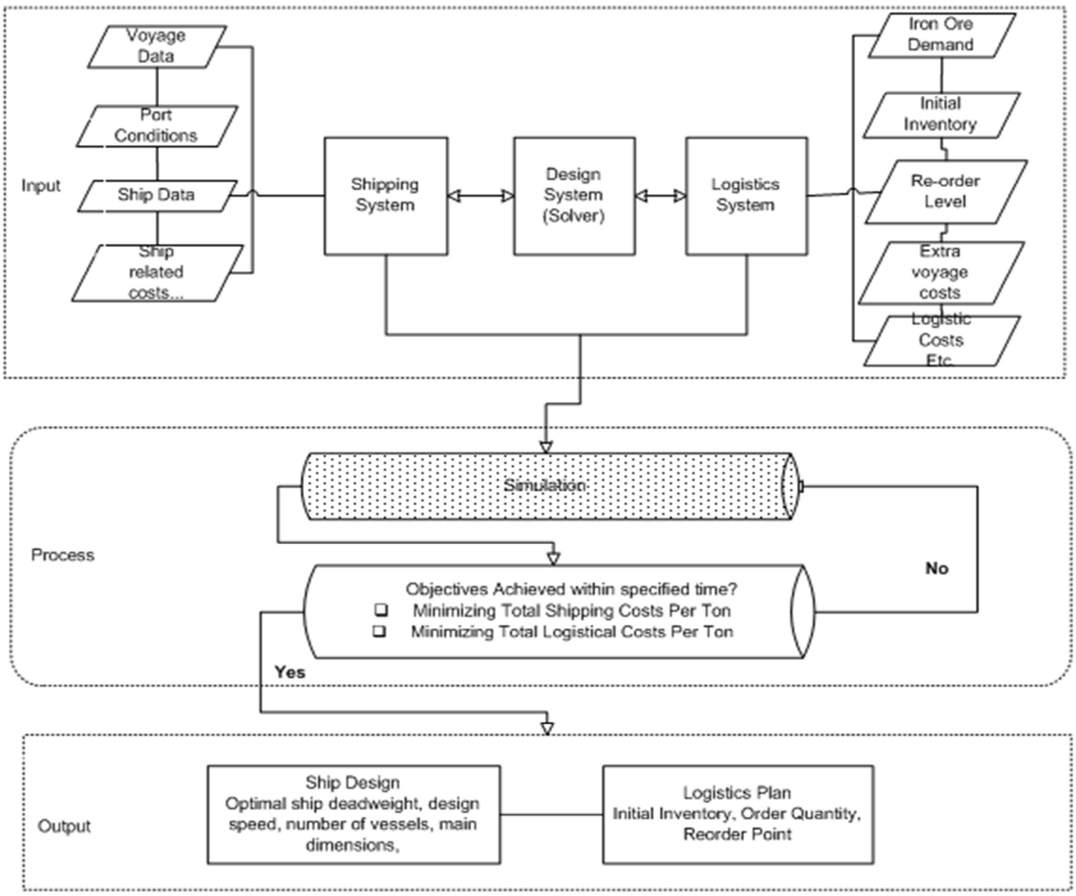

Figure 5.9: The optimization structure

Specifically, the optimization process starts with new initial values of deadweight and reorder level. Based on one deadweight, there are innumerable options for the design parameters. The optimum option is obtained through the Solver by achieving the minimal shipping costs per ton-mile. After the Solver, the optimum design parameters are exported such as deadweight, the economical speeds laden and ballast, the power installed, the fuel consumption per day, lightweight, and main dimensions. All of these outputs are utilized in the Monte Carlo simulation to make economic estimations. After each simulation, we can get the logistics cost per ton and obtain one set of outputs, including the main design parameters, the number of vessels, the reorder level and the initial inventory. The optimal solution achieving the minimum logistics cost per ton can be identified after all steps of simulation within the specified time. The Monte Carlo simulation procedure is illustrated in Figure 5.10, followed by its explanation.

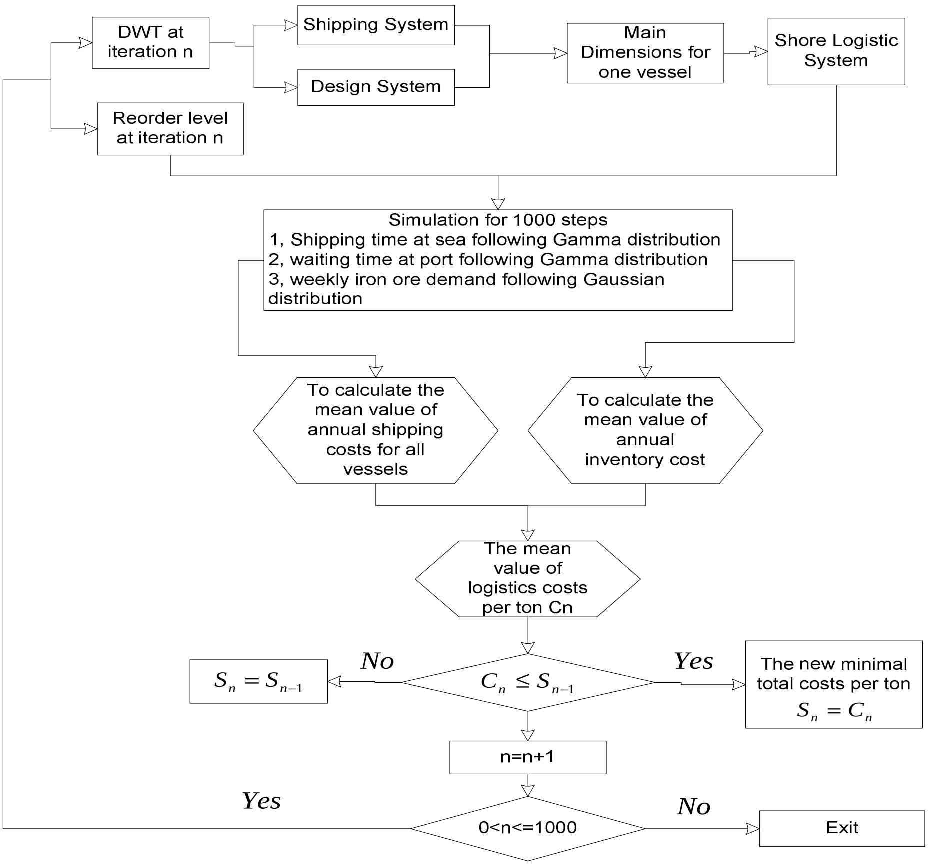

Figure 5.10: The simulation process

Monte Carlo simulation procedure:

Shipping costs per ton $C_s = f(dwt, T_s, T_p, D)$,

Shore logistic costs per ton $C_{inv} = f(dwt, q, T_s, T_p, D)$

Step 1: For $i = 1 \ \ to \ \ n$,

Generate random numbers $Y^i = (R^i(dwt), R^i(q))$

Step 2: For $j = 1 \ \ to \ \ m$

Generate random numbers $X^j = (R^j(T_s), R^j(T_p), R^j(D))$

Set $h_j = h(X^j) = f(dwt_i, T_{sj}, T_{pj}, D_j) + f(dwt_i, q_i, T_{sj}, T_{pj}, D_j)$

Set $C_i = \dfrac{h(X^1) + h(X^2) + ... + h(X^n)}{n}$

Step3: Set $S_0 = C_1$

If $C_i \le S_{i-1}$, then $S_i = C_i$

Otherwise $S_i = S_{i-1}$

Step 4: $i = i + 1$

If $i > n$ then the whole procedure stops

Otherwise Go to Step 1.

Where dwt means deadweight, q reorder level, T_s shipping time at sea, T_p total service time at terminals, D iron ore demand, R random number, h_j the logistic costs per ton, C_i the mean value of logistic costs per ton, S_i the minimal value of logistic costs per ton. n the number of iterations, m the number of trials for each iteration.

The optimization process starts from setting the initial values of decision variables. Using relevant basic parameters located in the input, all basic calculations are executed during each system. The results are then exported to the output by satisfying all constraints accordingly. After the maximum and minimum values of each constraint verify the result, the objective function is verified whether the new value of the objective function is less than that of the previous one. This process is repeated until obtaining the global minimum value.

5.5.2. Empirical analysis

The years since 2003 have witnessed the large expansion of seaborne trade of iron ore, a consequence of the huge demand for iron ore by China. In order to guarantee the steady supply of iron ore, large steel mills tend to sign long-term contracts with ship-owners or set up a new company with large ship owners to transport imported iron ore every year. Due to large amounts of iron ore needed to be shipped annually, the current fleet of ship-owners cannot meet the transportation demand, new ships, therefore, tend to be built in this case.

Under this background, the analysis is made to design dry bulk fleet with the optimum ship design, and to acquire the optimum logistics plan, which can achieve the economic objective for both ship owners and steel mills. Because annual imports from Brazil to China take up more than 20% among all China's iron ore imports since 2003, next to Australia, but the voyage between ports of Brazil-China is much longer compared to that of Australia-China, we assume the ships are used to serve the transportation of iron ore on the long voyage from Tubarao, Brazil to Beilun, China. The methodology described above is then applied into this specific case. The economic objective here is to minimize the total logistic cost per ton, determined by several variables, namely the shipping cost, the inventory cost of cargo and the annual tons of cargo carried.

Economic estimations in each system

Each of the three basic systems, including the design, shipping and logistics system, covers input, constraints, equations and output. All the basic calculations in each system are made by equations, such as various costs concerning ship operation and logistics plan, fuel consumption and the required revenues.

In the design model, the determination of ship resistance and power prediction is carried out using the power prediction method created by Holtrop and Mennen(1979). Three power calculations are made in the design model. One is for the installed power based on a maximum service speed of 14.5 knots. It's the average design (also maximum) speed of all bulk carriers built from 1975 to 2010 which is used to determine the initial engine investment consistently. Under the condition of the design speed larger than the optimum operation speed, we lock the design speed in our research at 14.5 knots. Statistical research showed that the design speed is independent from the size of the vessel.

The second one is the service speed at laden and the third one the speed at ballast. These two speeds are variables in the design module. They are fixed by determining altogether in one design calculation the main dimensions of the vessel, hull fullness coefficients, its weight, engine power, loaded and ballast economical speed, and as a consequence the fuel consumption under the condition that the costs per ton-mile are minimal for the determined set of basic parameters. This is an ideal job for a Solver, where a mathematical algorithm is built to determine the value of up till easily 20 variables under the constraint, in this case, of reaching the minimal costs per ton-mile, given a specific logistical profile.

Specifically, in our research, vessels are designed and built to transport iron ore on the specified consecutive round voyages during a fixed long period. The service speed, therefore, is little influenced by the market charter rate level, but by the bunker price level. We take the bunker price of IFO and MDO as the mean value of each during the past decade from 2000 to 2009, based on figures of Clarksons Intelligent Network (2010). Since bunker prices are fixed, the optimum operation speed can be achieved. A real freeboard calculation is added and the entrance angle has been made on a function of the Cb and other dimensions based on statistics. The detailed power calculations can be found in Appendix A-5.

The estimation of building costs is made using the approach of Aalbers(2000). The building cost of a ship comprises costs of nine systems in a ship, including general and engineering system, hull and conservation, ships equipment, accommodation, electrical system, propulsion and power generation, systems for propulsion and power generation, bilge and ballast system and cargo system. These calculations employ material costs, man hours, labour costs and many constants taken from many related sources. Every optimization of the main design parameters is achieved by the Solver. The target of the Solver in the research is to minimize the shipping costs per ton-mile. This economic target is determined by the capital cost, the operation cost, the voyage cost and the shipping distance, while the latter two are dependent on the figures of the shipping system.

In the shipping system, the voyage data part is one of the vital ones in the optimization model. Voyage figures such as the total annual operation days, the trip distance, margin time at sea and port, loading factors, port loading and discharging rates, as well as the harbour unit cost are all collected from Chinica Shipbrokers Co., Ltd. The estimated daily fuel consumptions at ballast and laden, are close to the practical data. To determine the number of voyages per year, a non-integer number of operated ships might be generated. Both the number of voyages and the number of operated vessels in the research should be integer and they are determined by the simulation process. As mentioned above, the shipping time at sea and the service time at terminals are assumed to follow a gamma distribution. The scale is set to be 0.8, shape 2 and location 0 in gamma distribution functions of shipping time both at the laden speed and the ballast speed. It means the average time margin at sea is 1 days (3% of the shipping time), and the unexpected time at sea ranges from 0 to 3.0 days with certain probability for one laden voyage. In the shore operations, the loading rate at Tubarao, Brazil can reach 85,000 tons daily on average and the discharging rate can be 30,000 tons daily on average at Beilun, China under ordinary conditions, according to the data provided by Wilhelmsen Ships Service Ltd. Besides this expected service time at both terminals, we also incorporate the unexpected time into the calculation. We assume the unexpected time at both terminals follows a gamma distribution and the parameters in the gamma function are determined as 1 for scale, 3 for shape and 0 for location. In other words, the unexpected time ranges from 0 to 9 days with certain probabilities for both terminals. All the figures are obtained by the interview with ship-owners.

When it comes to the calculation of the capital cost, it is related with the new-building price, loan repayment scheme and the depreciation plan. In the research, the new-building price is estimated based on the building cost plus a certain percentage of profits. In our case, we assume the equity takes up 60 %, while loan 40 % with a 6 % interest rate for the redemption within 10 years. The choice of the optimal deadweight is not influenced by the different combinations of financing the new-building vessels. The results can be available from authors. The operating cost comprises the repair and maintenance, stores and lubricants, insurance, crew cost and management cost. The estimation in Aalbers (2000) is used to work out the total operating cost, among which, the repairs and maintenance take up approximately 0.5% of the ship value, stores and lubricants 0.4% of the ship value, insurance 1% of the ship value, crew expenses 0.5% of the ship value for 20 crew and management cost 6% of the total fixed cost. The estimated operating cost is close to the cost constructed from Drewry dry bulk forecaster (2007).

In the shore logistic system, iron ore demand follows a normal distribution. The maximal iron ore demand per year can be estimated based on the annual maximum steel production capacity. We assume 1 metric ton of steel needs 1.67 metric tons of iron ore with an average iron content of 60%. The mean value is estimated as 90% of the maximal demand, which means the furnaces are 90% utilized. The standard deviation is 3% of the mean value. Secondly, order quantity Q refers to one shipment quantity, and the order cost here is the interests incurred during the transport time. The initial inventory should meet the demand for iron ore during the total round voyage time. Lead time here denotes the actual round voyage time for each shipment. Thirdly, the holding cost means interests and storage cost during the storage period at the yard. The lost sales cost should be the profit lost of steel makers arising from the lost production.

At the beginning of each week, if any outstanding orders have arrived, the manager adds the order quantity to the current inventory level. Then, the manager should determine the weekly demand and check if sufficient inventory is on hand to meet this demand. If not, the number of lost sales is the demand minus the current inventory. Then, the manager should subtract the current inventory level from the inventory position, set current inventory to zero, and compute the lost sales cost. If sufficient inventory is available, all demand will be satisfied from the stock and both the inventory level and the inventory position should be reduced by the amount of demand.

The next step is to check if the inventory position is at or below the reorder point. If so, place an order for Q units and compute the order cost. The inventory position is increased by Q, but the inventory level remains the same. Schedule a receipt of Q units to arrive after the lead-time.

Finally, to compute the holding cost based on the inventory level at the end of the week (after the demand is satisfied) and the total cost. The total cost covers the holding cost, the order cost and the short cost if any.

Further description of the simulation

For the ship-owner, it is required to design a number of series dry bulk ships, which have the optimum main dimensions and the optimum specified power. For the steel mill, the optimum logistics plan should be made, including the initial inventory, order quantity, reorder point and lead time. In the optimization process, deadweight and reorder point are set as decision variables, which are varied within the specified range. The value of deadweight ranges from 80,000 dwt to 500,000 dwt, while the reorder point ranges from 1 ton to 4000,000 tons, the latter is large enough. Forecast variable is the logistics cost per ton, utilized as the objective of the optimization problem. In other words, the minimum logistic cost per ton must be obtained to guarantee that the optimum design and logistics plan can be achieved. The minimum and maximum values of the constrained parameters in the design model have been determined in advance. The limitations of the design variables in the design model can be seen in Table 5.19. The draft limitation and the maximum allowable draft are automated as a function of the design deadweight by using a trend. This creates a much greater range for the ship design. The maximum draft is set to be 23 meters for both loading and discharging terminals in our research. The draft limitation has a great impact on the ship design.

Table 5.19: Limitations of design variables

	Loa	Lwl	B	Cb	V
Minimum	100	100	0	0.7	8
Maximum	500	500	10	0.9	20
	L/D	L/B	T/D	T	Dwt
Minimum	10	5.5	0	0	80000
Maximum	14	7.5	1.0	23.0	500000

The whole optimization process is repeated for 1000 times. 1000 iterations are enough to get the optimal solution, which will not be changed after 900 iterations in the empirical test. For each iteration, the simulation is run for 1000 trials. The reason why we set 1000 trials for each iteration is that the standard error of the mean value for the forecast variable, e.g. the logistics cost per ton is controlled to be smaller than 10%. The adaptive and neural network technologies are applied into the Crystal Ball to reduce time in searching for better results. Before each step of simulation, local optimum values for design variables are got by solving the design model with one initial value of deadweight, whilst keeping constant the maximum and minimum values of constraints. Afterwards, for one value of the reorder point, the logistics cost per ton can be worked out through 1000 trials. If the logistics cost per ton is lower than the previous cost, the cost and outputs will be saved, otherwise, previous ones are still the best values. After 1000 iterations, we can get the minimal logistics cost per ton, together with other outputs.

Optimization results

The optimal combinations of ship design and the logistics plan for various annual iron ore transport demand are acquired. The iron ore demand is dependent on the steel production of a steel plant. Four different steel production capacities have been chosen: 1 million, 3 million, 5 million and 7 million tons per year, and the iron ore required every year for each steel production capacity is 1.66 million, 4.98 million, 8.30 million and 11.62 million tons, respectively. The summary of the optimization results for four models, each with a different iron ore throughput, is illustrated in Table 5.20. It is observed that the optimization results are very sensitive for diverse models. The determination of the minimum and maximum values of the constraints and the outputs, which determine the feasible area of the optimization, is the privilege of the designer. To get an impression by the accuracy of the design model, the existing vessel Peen Ore built in 1997 has been added in Table 5.20.

Several conclusions can be drawn from the results. Firstly, the optimal ship size in each model is dependent on iron ore demand and logistics plan due to the shore logistic system incorporated into the optimization process, and there seems to be a tendency towards bigger vessels and higher reorder point/level when transport demand becomes larger, which can be shown in Figure 5.11. Because the number of vessels must be integer, the optimal ship/ships should be the one/ones, which can be utilized efficiently to match the ordering and inventory plan best. In other words, the average idle time of each vessel waiting for orders should be limited at a reasonable level in order to reduce the logistics cost. Suppose a vessel is running 350 days per year, the idle time for the optimal ship size in each model can be obtained after the whole optimization process, as seen in Table 5.21.

Table 5.20: Simulation results of different transportation demand with maximum draft limited at 23 meters

Steel production	1.000.000	3.000.000	Peen Ore (1997)	5.000.000	7.000.000	t/year
Max. Iron Ore demand	1.660.000	4.980.000		8.300.000	11.620.000	t/year
Dwt	225000	335000	332398	375000	390000	Ton
Loa	309.56	335.13	332.0	352.91	359.41	m
Lwl	302.01	326.96	326.0	344.30	350.65	m
B	52.83	59.45	58	62.60	63.75	m
D	25.66	30.61	30.2	30.55	30.53	m
T	19.19	23.00	23	23.00	23.00	m
Cb	0.802	0.807	0.804	0.815	0.817	
V laden econ.	12.23	12.19		12.19	12.20	knot
V ballast econ.	13.31	13.15		13.09	13.08	knot
V design	14.50	14.50	14.7	14.50	14.50	knot
Wsm	27909	36745	37538	40986	42607	ton
Pb installed	19009	24026	25849	26188	26975	kW
Costs per ton-mile	0.00178	0.00159		0.00157	0.00157	$/t-mile
Number of vessels	2	4		6	8	
Idle time waiting for orders	5.5%	2.9%		2.3%	1.1%	
Reorder level	375.00	1207.00		2100.00	3000.00	ton
Initial inventory	367.38	1155.31		1962.86	2767.33	ton
Logistic costs per ton	23.13	20.81		20.06	19.65	$/ton

Table 5.21: Simulation results of different transportation demand with maximum draft limited at 20 meters

Steel production	1.000.000	3.000.000	5.000.000	7.000.000	t/year
Max. Iron Ore demand	1.660.000	4.980.000	8.300.000	11.620.000	t/year
Dwt	225.000	330.000	380.000	395.000	ton
Loa	309.5	356.3	380.7	382.2	m
Lwl	302.0	347.6	371.5	372.8	m
B	52.8	62.8	67.1	67.7	m
D	25.66	26.5	26.5	26.6	m
T	19.19	20	20	20	m
Cb	0.802	0.820	0.828	0.847	
V laden econ.	12.23	12.18	12.19	11.99	knot
V ballast econ.	13.31	13.06	13.02	12.81	knot
V design	14.50	14.50	14.50	14.50	knot
Wsm	27909	39460	45529	46384	ton
Pb installed	19009	25122	28054	30168	kW
Costs per ton-mile	0.00177	0.00166	0.00164	0.00164	$/t-mile
Number of vessels	2	4	6	8	
Reorder level	385	1210	2200	3010	ton
Initial inventory	363	1156	1972	2812	ton
Logistic costs per ton	23.13	21.78	20.70	20.66	$/ton

When one vessel is required, days off hire due to no shipment orders take up around 5.5% of the total operation days. When a fleet is needed, the idle time ratio can be limited below 3%. This may be partly explained by the more flexible scheduling plan and more efficient utilization of vessels for a fleet. Through the simulation, ship owners can get ideas of how much time the vessel may spend waiting for orders during the integrated logistic system. When the optimization process is completed, the associated unit costs are achieved including the unit shipping cost and the unit logistics cost, as shown in Figure 5.12. The simulated distribution of the unit logistics cost for each optimal ship size in four models can also been got, as displayed in Figure 5.13.

Secondly, the results suggest economical speeds, at which the ship is preferably operated to reduce fuel costs when there is sufficient cargo demand. Economical speeds are around 12 knots at laden and 13 knots at ballast when IFO price is $300/ton and MDO price $480/ton. The ship always consumes slightly less fuel oil in the ballast condition. The economical speeds are produced and do not deviate much if new calculations in the design model are made with the same inputs. However, changes to the bunker prices and the design speed have a substantial impact on the economical speeds. For instance, in the optimization model of 1.66 million tones iron ore demand annually, when the bunker prices soar to $450 and $600 per ton for IFO and MDO, the economical speed at laden is reduced from 12.23 knots to 10.80 knots.

Thirdly, constraints on the port draught determine main dimensions of a vessel. The current existing ships are all draft limited. No draft limit means a much larger depth and draft at the cost of width, minimising wet area and lightship. In our optimization model, the draught is limited up to a maximum of 23 meters. When the maximum draught limitation is changed to 20 meters, results obtained from the same optimization process reveal that there seems to be a distinct tendency towards larger block coefficients in combination with wider vessels, and both the shipping costs per ton-mile and the logistic costs per ton are increased, which can be illustrated in Figure 5.14. The detailed results for 20 meters maximum draught can be seen in Table 5.21. The sensitivity of the design mainly depends on the input parameter values, the width of the constraint as well as the preciseness of the adopted equations.

Finally, the inventory cost is largely dependent on the order quantity and the reorder level. There is a trade-off between both. A larger reorder point will create a higher inventory level on average, resulting in a lower total shortage cost but a higher total holding cost. A larger order quantity will incur lower ordering costs resulting from ordering less frequently. The optimal order quantity and reorder level after simulation can result in the relatively lowest possible inventory cost, even when there is still variability in the weekly iron ore demand.

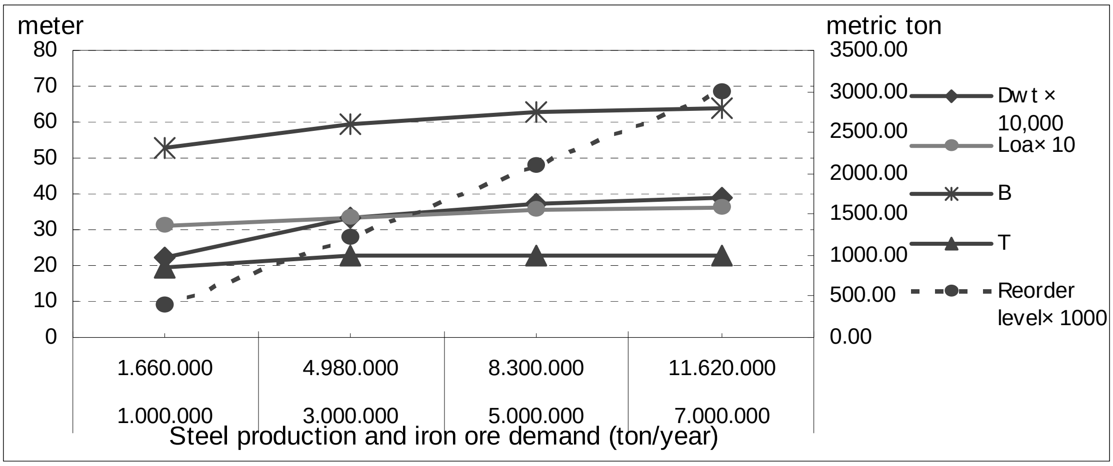

Figure 5.11: The optimum ship size, main dimensions and the number of vessels in four models

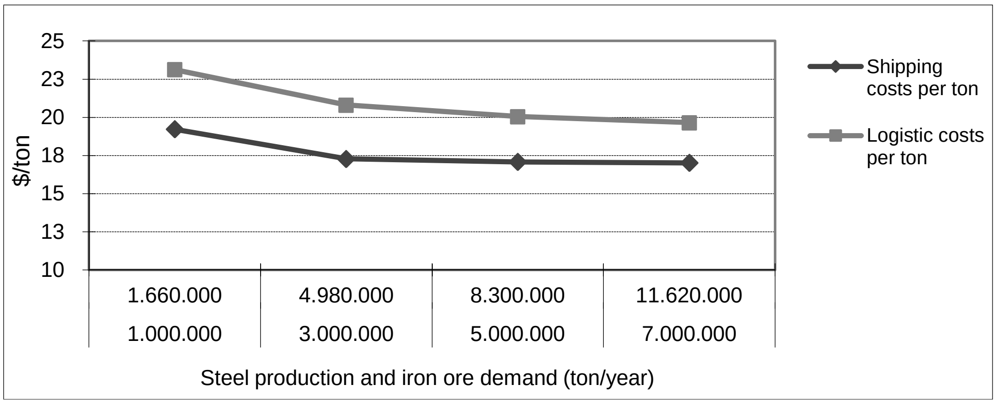

Figure 5.12: The optimum shipping costs per ton-mile and logistic costs per ton in four models

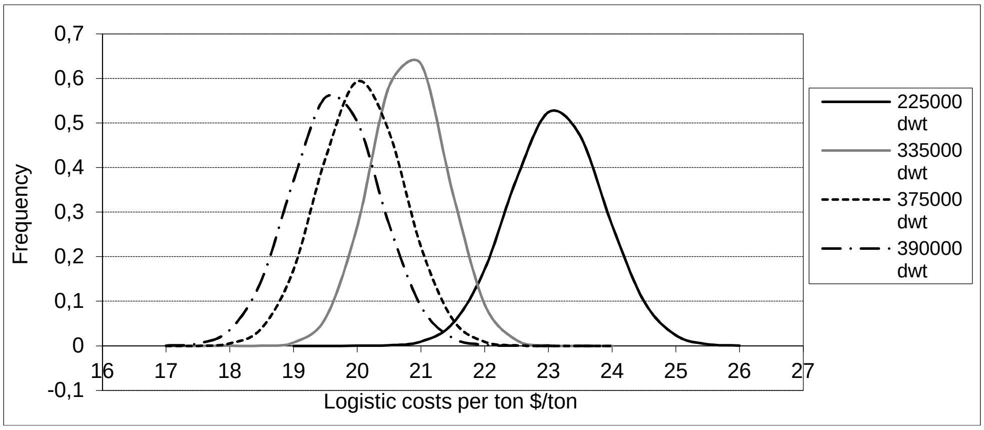

Figure 5.13: The simulated unit cost distribution for each optimal ship size in four models

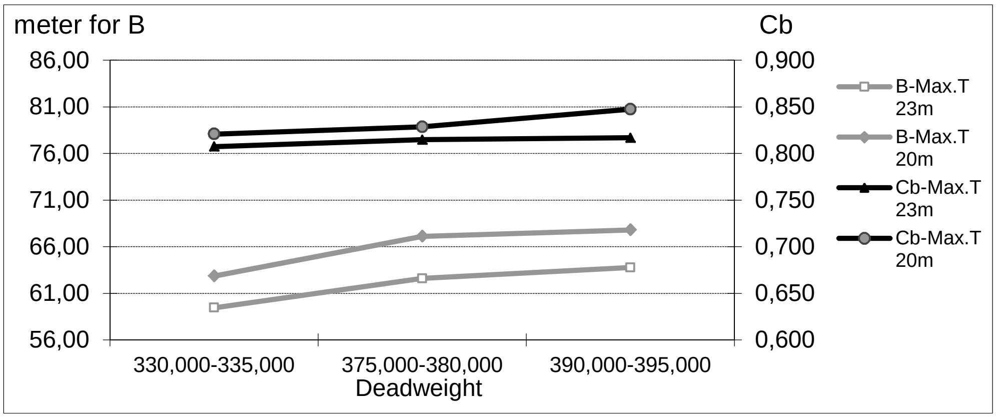

Figure 5.14: The different breadth and block coefficient of various ship deadweight for draft limitations at 20 meters and 23 meters, respectively.

This optimization methodology has the required flexibility in the decision-making for both ship owners and steel mills. Additional tasks can easily be added within the optimization model. By adding constraints to some variables, such as initial inventory and draft, or by changing some variables, such as the annual transport demand of iron ore and the specific voyage, we can get different results. This kind of optimization process can also be utilized to either to minimize or to maximize the objective function. Further sensitivity analysis can also be made to investigate the influence of input variables on outputs and economic objectives.

5.6. Conclusions

This chapter examines volatilities of newbuilding ship prices, dynamic relationships between newbuilding ship prices and charter rates, and relationships between ship prices including new-building, the second-hand and scrap prices. Based on these studies, time-series models of forecasting newbuilding prices are constructed and the forecasting performance of each model is evaluated. Furthermore, in the newbuilding market, shipowners and/or investors are not only interested at prices, but also the ship design. Most vessels are designed to buyers' specification, though there are standard ship designs for dry bulk vessels in the shipyard. The optimization of ship design to buyers' specific requirements is discussed in this chapter.

Tests on the volatilities of new ship prices for three types of dry bulk vessels are made during the sample period from Dec 1991 to Dec 2010 for Capesize, and from Jan 1990 to Dec 2010 for Panamax and Handymax. It is indicated by results that newbuilding prices do not exhibit conditional variance and are not as volatile as second-hand ship prices.

The investigation into the relationship between charter rates in the freight markets and newbuilding ship prices in the ship market for three main types of dry bulk vessels reveals that there are cointegration relationships between charter rates and newbuilding prices, and newbuilding prices are primarily determined by prices in the freight market. The newbuilding ship prices seem not be affected by prices in the second-hand ship market and the scrap market. The monthly US dollar index, representing changes in the exchange rate of the US dollar against other currencies, and steel prices, representing the production costs, seem not to have significant impacts on prices of new vessels. However, the LIBOR representing the financial liquidity, exhibit the mixed results for different ship size. Although charter rates have a significant impact on newbuilding prices, the incorporation of charter rates in the forecasting models does not help improve forecasting performance, and the time series model yielding the best forecasting results is the ARMA model at various forecasting horizons for three types of vessels.

Furthermore, in the shipbuilding market, important issues to buyers include not only when to order, but also what kind of vessels to order. Buyers always intend to build a new vessel with the optimal design according to their requirements. This chapter, therefore, proposes an integrated scheme of the technical, logistical and economic analyses for buyers or ship owners to optimize the ship design, particularly in determining the main technical specifications, including main dimensions, deadweight, design and economical speed, and the power requirement at the conceptual design stage.

The case study is executed for iron ore transportation during the voyage from Tubarao, Brazil to Beilun, China. Three basic systems, namely the basic design model, the shipping system and the shore logistic system, have been set up to carry out the analysis. The whole optimization process is completed through the Monte Carlo simulation within the spreadsheet based Crystal Ball software by embedding the Microsoft Solver to deal with the design solution. The optimum ship main dimensions, speed, power requirement, number of vessels, and logistics plan are all obtained through the optimization model. For various iron ore transport demand, different optimization models are produced and distinct results are obtained.

The proposed methodology not only provides a tool to analyze the trade-off between total transport costs and inventory costs, but it also provides an insight in the interdependency of shore facilities, logistical aspects and the ship design, and can offer the required flexibility in the decision-making for both dry bulk ship-owners and steel mills.

Chapter 6. Modelling Price Behavior in the Second-hand Ship Market

The market for second-hand ships is one of the most important integrated parts of the shipping industry, and this chapter presents an investigation into the second-hand ship market for three types of dry bulk vessels. This market is the one where second-hand ships can be traded by market participants, for instance, ship-owners and asset-players for diverse purposes. Kavussanos and Alizadeh (2002b) argue that for investors, known as speculators or asset players, they usually participate in the sale and purchase market to rely more on capital gains rather than operational revenues of vessels. For another group of investors, they are more interested in operating profits rather than capital gains. Because it usually takes a few years to build a new vessel, the second-hand ship market becomes an alternative source for ship-owners to satisfy their instant demand for tonnage. Since the sale or purchase of vessels is not likely to change the tonnage supply of the market, a key function of this market is to reallocate vessels among ship operators and to facilitate the market entry or exit by allowing potential investors to buy a used vessel or sell it.

It is undoubted that the ship market is strongly linked to the freight market, because the price of a second-hand vessel depends on ship-owners' expectations regarding the future movement of the freight market, and in turn, the revenue generated from the freight market provides the capital for ship-owners to acquire new or second-hand vessels. Thus, we can always find the price of a second-hand vessel rises during a freight boom, and drops during a freight depression. Apart from prices in the freight market, prices in the newbuilding, the second-hand and scrapping markets may be interrelated among themselves, since changes in the newbuilding and the scrapping markets can bring changes to the tonnage supply in the shipping market, thus may have an impact on the evaluation of second-hand ship values. Furthermore, there are other variables that would influence ship values, for example, the exchange rate and the interest rate. Consequently, to find out the driving forces behind second-hand ship prices and the way they influence ship prices would offer investors some useful insight into the timing of their investments in the second-hand ship market.

The next section first examines volatilities of ship prices in the second-hand market for three types of vessels. The investigation on interrelationships between second-hand ship prices and charter rates in the freight market is presented in Section Two. The relationships between the second-hand ship, the new-building, the scrapping prices and charter rates are discussed in Section Three. Based on the in-depth analysis, Section Four describes various forecasting models in the prediction of second-hand ship values and explains different forecasting results.

6.1. The time-varying volatilities of ship prices in the second-hand ship market

The volatilities of newbuilding ship prices are discussed in Chapter 5 and it is found that the variation of newbuilding prices do not vary over time. Whether or not it is the same case in the second-hand ship market is up to the investigation. Typically, second-hang ship prices will respond sharply to changes in market conditions, and may be increased or decreased within a short period. This section presents the examination of the stationarity properties of monthly second-hand ship prices and the variation of these prices for Capesize, Panamax and Handymax vessels.

6.1.1. Methodology

GARCH models are very useful in dealing with the volatility clustering of high frequency data, so the GARCH and GARCH-X models are employed in this section to investigate whether the variation of second-hand prices changes over time, and whether they are dependent on the different market conditions.

However, a conventional GARCH model is unable to capture the asymmetric effect of negative or positive returns on the volatility. This effect occurs when an unexpected drop in price increases volatility more than an unexpected increase in price of a similar magnitude. The existence of this asymmetric effect implies that a symmetric specification on the conditional variance function as in a conventional GARCH model is theoretically inappropriate. To address this issue, we may employ Nelson's EGARCH model, the detailed specifications of which can refer to Appendix A.

6.1.2. Description of data and statistical properties

In this part, monthly second-hand prices for a 5-year-old Capesize vessel of 170,000 dwt, a 5-year-old Panamax of 76,000 dwt, and a 5-year-old Handymax of 56,000 dwt come from both Clarkson Research Studies Ltd and the Baltic Exchange. Between October 2008 and January 2010, Clarkson research company did not publish benchmark values because it is a period of transition in the sale and purchase markets, characterized by spells of rapidly changing price levels, low levels of sales activity and a wide spread of price ideas. During this period, the Baltic Exchange continued publishing second-hand ship prices. Furthermore, figures of Handymax of 56,000 dwt are only available since Jan 1986. In light of both, figures from 1986 to 2003 are from Clarkson Research Studies Ltd, and those since 2004 are obtained from the Baltic Exchange. The comparison of prices from Clarkson and the Baltic Exchange over the same period from Oct 2003 to Sept 2008 indicates the price series from both sources are very close with correlation coefficients being 0.9939, 0.9968, 0.991 for Capesize, Panamax and Handymax, respectively. Our sample period is then from Jan 1986 to Dec 2010, yielding a sample of 300 observations. The movement of second-hand ship prices over time can be shown in Figure 6.1. It is revealed that all the ship prices move together in the long run, however, the behavior of each ship size in the short run is not identical and the different short term dynamics might be related to differences in the market structure and characteristics of each segment.

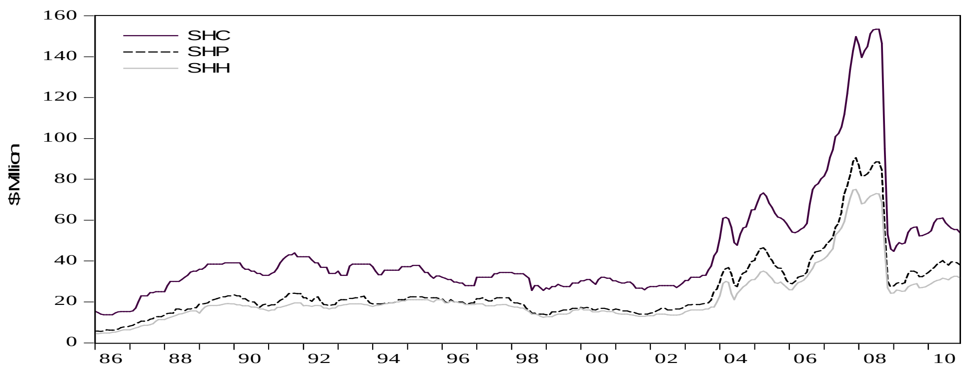

Figure 6.1: Second-hand ship prices for Capesize, Panamax and Handymax during Jan 1986 to Dec 2010

Notes: SHC=second-hand ship prices for Capesize; SHP=second-hand ship prices for Panamax; SHH=second-hand ship prices for Handymax

The summary statistics of monthly rates of change in the transformed ship prices over the sample period are in Table 6.1. The results indicate that the mean values of monthly returns of bigger vessels seem to be lower than smaller ones. It implies higher returns may be achieved by trading smaller vessels than larger ones during the same period. A comparison between the sample standard deviations reveals that Capesize prices are more volatile than the other two sizes. In other words, the Capesize variation in rates of price changes over the entire period is higher than that of the other two sizes. Even though the Capesize variation is higher than the Panamax, the result is not significant at the 5% level. Additionally, the Panamax variation is significantly higher than that of Handymax. The leptokurtic property of the sample distributions of monthly returns is also evident in the summary statistics. Both the coefficients of skewness and kurtosis indicate excess skewness and kurtosis across the data. The normality test summarizes these findings, showing fat tails of the distributions.

Table 6.1: Descriptive statistics of monthly rates of change in ship prices for three types of vessels

	ILSC	ILSP	ILSH
N	299	299	299
Mean	0.0044	0.0063	0.0065
Median	0.0000	0.0000	0.0000
Std. Dev.	0.065	0.064	0.057
Equality test*	1.02	1.12	1.14
Skewness	-4.05 [0.00]	-4.01[0.00]	-3.88[0.00]
Kurtosis	39.93[0.00]	39.73[0.00]	37.62[0.00]
Jarque-Bera	17812[0.00]	17107[0.00]	16119[0.00]
Q(20)	114.25	107.57	115.86
Q^2(20)	62.10	40.773	58.448
ADF(lags) (Lev)	-2.46(1)	-2.54(1)	-2.93(1)
PP(lags) (Lev)	-2.26(7)	-2.39(7)	-2.72(6)
ADF(lags) (1st diffs)	-10.93(0)	-10.78(0)	-10.28(0)
PP(lags) (1st diffs)	-10.72(4)	-10.69(4)	-10.05(6)

Notes:

♦ ILSC means the logarithmic first differences for Capesize, ILSP the logarithmic first differences for Panamax, and ILSH the logarithmic first differences for Handymax.

♦ N is the number of observations; Figures in square brackets [·] indicate exact significance levels

♦ Skew and Kurt are the estimated centralized third and fourth moments of the data; their asymptotic distributions under the null are $T\hat{\alpha}_3'\hat{\alpha}_3 / 6 \sim \chi^2(1)$ and $T(\hat{\alpha}_4 - 3)'(\hat{\alpha}_4 - 3)/24 \sim \chi^2(1)$ respectively.

♦ Q(20) and Q^2(20) are the Ljung and Box (1978) Q statistics on the first 20 lags of the sample autocorrelation function of the raw series and of the squared series; these tests are distributed as $\chi^2(20)$ .The critical values are 37.57 and 31.41 for the 1% and 5% levels, respectively.

♦ J-B is the Jarque-Bera (1980) test for normality, distributed as $\chi^2(2)$

♦ ADF is the Augmented Dickey and Fuller (1981) test. PP is the Philips and Perron(1988) test; the truncation lag for the test is in parentheses. The 5% critical value for the ADF and PP tests is -2.87; the 1% critical value for the ADF and PP tests is -3.45.

♦ * The hypothesis of equality of the unconditional variances of returns between pairs of vessels can be tested using the statistic $F = V_1 / V_2 \sim F(n-1, m-1)$, V_1 and V_2 are sample variances, n and m are the number of observations used to compute each variance. The F-statistic for Capesize versus Panamax is 1.02, for Panamax vs Handymax is 1.12, for Capesize vs Handymax is 1.14. Critical value of the statistic at the 5% level is 1.08.

In order to fit a time-series model to monthly variables, variables should be stationary. The results of Augmented Dicky-Fuller (ADF,1981) and Philips-Perron (PP,1988) unit root tests indicate that there is a unit root for ship prices at level, but this stochastic unit root can be removed by transforming variables into first differences.

The Ljung-Box Q(20) statistics (Ljung-Box, 1978) of the stationary series reveal high degrees of serial correlation in the conditional means of the variables. The Ljung-Box $Q^2(20)$ statistics (Ljung-Box, 1978) demonstrate the existence of heteroskedasticity for the returns for all sizes at the 5% significance level.

6.1.3. Empirical results

Significant serial correlation is found for returns of second-hand ship prices, because transactions are concluded through specialist brokers based on private and confidential negotiations between the interested parties in the sale and purchase market. One of the primary functions of a sale and purchase broker is then to collect, compile and process information from market sources, and they will report prices of transactions that have taken place in the market; or assess them arbitrarily in absence of no transactions or no transparent transactions. The time series ARMA model may then be fitted to model these conditional means for three types of vessels. The AIC and SBIC criteria are employed to choose the lag length of the ARIMA model in the mean equation. Heteroskedasticity is displayed for the returns in all cases. The GARCH(1,1) model is consequently used to investigate the persistence characters of the variance of second-hand ship prices. Table 6.2 presents the results.

Table 6.2: Estimates of the mean and volatility of second-hand ship prices for dry bulk vessels

$$\Delta X_t = \varphi_0 + \sum_{i=1}^{p} \varphi_i \Delta X_{t-p} + \varepsilon_t, \quad \varepsilon_t = \sqrt{h_t} z_t, \ z_t \sim iid(0,1)$$

$$h_t = \omega + \alpha \varepsilon_{t-1}^2 + \beta h_{t-1}$$

Panel A: Estimates of various models

Capesize		Panamax		Handymax	
φ_1	0.361** (6.938)	φ_1	0.386** (7.488)	φ_1	0.447** (8.811)
ω	0.001** (3.765)	ω	0.0006* (1.647)	ω	0.0005* (1.789)
α	0.389** (2.207)	α	0.206 (1.628)	α	0.440* (1.853)
β	0.187 (1.240)	β	0.638** (4.696)	β	0.487** (3.957)

Panel B: Diagnostic tests on standardized residuals of models for three types of vessels

	Capesize	Panamax	Handymax
J-B normality test	6054 [0.00]	3941[0.00]	3016 [0.00]
$\bar{R}^2$	0.241	0.231	0.268
AIC	-3.785	-3.459	-3.887
SBIC	-3.736	-3.397	-3.824
Q(20)	26.791[0.141]	26.235[0.158]	23.743[0.254]
$Q^2(20)$	10.357[0.96]	5.49[0.99]	8.344[0.99]
Persistence ($\alpha_i + \beta_i$)	0.576	0.844	0.927
Sign bias	1.031[0.311]	1.054[0.305]	0.487[0.485]
Negative size bias test	0.78[0.400]	0.215[0.643]	1.374[0.241]
Positive size bias test	0.821[0.368]	0.442[0.506]	0.094[0.758]

Notes:

- All variables are transformed in natural logarithms.
- ** and * indicate significance at the 5% and the 10% level, respectively.
- Figures in parentheses (.) and in squared brackets [·] indicate t-statistics and exact significance levels,

respectively.

- J-B Normality is the Jarque and Bera(1980) normality test, with probability values in square brackets.
- $Q(20)$ and $Q^2(20)$ are the Ljung and Box (1978) tests for 20th order serial correlation and heteroskedasticity in the standardized residuals and in the standardized squared residuals, respectively.
- The persistence coefficient is calculated as $\alpha_i + \beta_i$.
- The test statistics for the Engle and Ng(1993) tests are the t -ratio of φ_1 in the regressions; sign bias test: $\varepsilon_t.h_t = \varphi_0 + \varphi_1 S_{t-1}^{-} + e_t$; negative size bias test: $\varepsilon_t.h_t = \varphi_0 + \varphi_1 S_{t-1}^{-}\varepsilon_{t-1} + e_t$; positive size bias test: $\varepsilon_t.h_t = \varphi_0 + \varphi_1(1 - S_{t-1}^{-})\varepsilon_{t-1} + e_t$. Where $\varepsilon_t.h_t$ is the squared standardized residuals, S_{t-1}^{-} is a dummy variable taking the value of one when ε_{t-1} is negative and zero otherwise.

The heteroskedasticity of the return series means the variance of these return series is conditional and time-varying. Thinking of coefficients of α and β, it can be seen in Table 6.2 that the magnitude of these coefficients varies between markets. The coefficient α is 0.44 in the Handymax sector, where the new shocks seem to matter most, while it is 0.389 for Capesize and falls to 0.206 for Panamax. The Panamax sector seems to be affected most by the old news with the coefficient β being 0.638, followed by the Handymax and Capesize. It implies that the conditional volatility differs between various size vessels. Findings here are consistent with results in Kavussanos (1997).

The GARCH (1,1) specification is found to be appropriate for modelling the time-varying volatilities in all cases with the lowest SBIC and there is no evidence of serial correlation and heterosckedasticity, as indicated by the Ljung-Box $Q(20)$ and the Ljung-Box $Q^2(20)$ statistics (Ljung-Box,1978). Diagnostic tests confirm that all models are well specified and the sign and size bias tests do not indicate any asymmetric effects of shocks on conditional variances in the selected models. The EGARCH model, therefore, is not employed to examine the asymmetric effects.

Results in Table 6.2 reveal that the GARCH process of second-hand ship prices is stationary in all cases, but the variation of the investigated time series demonstrated in Figure 6.2 seems more dramatic since 2003. In order to investigate the possibility that the volatility of the return series of ship prices significantly varies under different market conditions, we incorporate a dummy variable in the conditional variance of returns. The specification can be seen as follows.

$$h_t = \omega + \alpha\varepsilon_{t-1}^2 + \beta h_{t-1} + \delta d_1$$
$$d_1 = 0 \ \ during \ 1986.1 - 2002.12; \ d_1 = 1 \ \ during \ 2003.1 - 2010.12 \qquad (6.1)$$

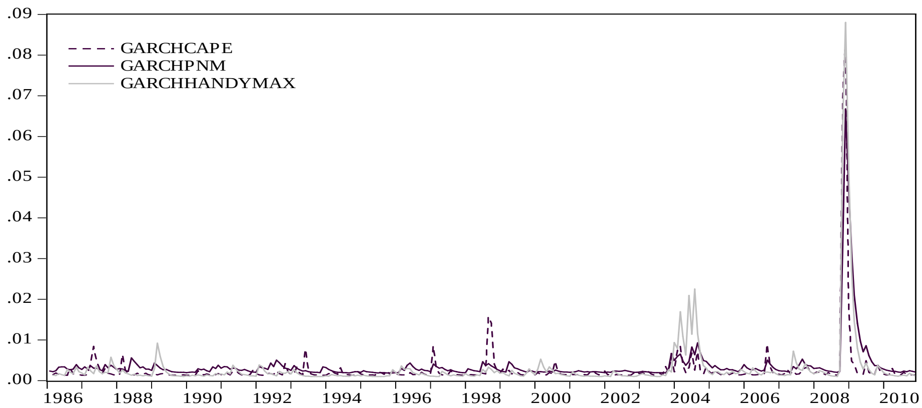

Figure 6.2: The variation of returns of second-hand prices for three types of dry bulk vessels

The ARIMA-GARCH-X model under which a dummy variable is introduced in the variance is estimated in an attempt to explain the dynamics of variation of return series, and results are reported in Table 6.3. The inclusion of the dummy variable in the variances captures some of the volatility persistence in the GARCH model, bolstered by the lower value of normality test and the smaller number of the sum of GARCH coefficients. The dummy variable, however, is not significant at the 10% significance level in the GARCH specification in all cases, implying that the conditional variation of the return series does not vary significantly over two sub-periods before and after 2003, although the unconditional variance over the period after 2003 is increased. This finding is not consistent with the finding found for the volatility in the freight market, and it implies that second-hand ship prices are less volatile than prices in the freight market.

Regarding the volatility level, sharp hikes of the volatility can be seen over the relatively booming period 2004-2005, the financial crisis period in 2008 and its subsequent recovery period in 2009 in three ship size sectors. Periods with large imbalances are normally associated with higher volatility, due to the sudden change in demand and the infrequent trading which may cause prices to deviate substantially from fundamentals. Increases in the trading activity, probably due to speculative trades or the asset-play, may ensure that ship prices do not depart substantially from economic fundamentals; this in turn leads to more efficient pricing and reduces volatility.

Table 6.3: Estimates of the ARMA-GARCH-X model for second-hand ship prices

$$\Delta X_t = \varphi_0 + \sum_{i=1}^{p} \varphi_i \Delta X_{t-p} + \varepsilon_t, \quad \varepsilon_t = \sqrt{h_t} z_t,\, z_t \sim iid(0,1)$$

$$h_t = \omega + \alpha\varepsilon_{t-1}^2 + \beta h_{t-1} + \delta d_1$$

Panel A: Estimates of various models

Capesize		Panamax		Handymax	
φ_1	0.386** (6.158)	φ_1	0.372** (7.386)	φ_1	0.429** (8.626)
ω	0.001** (4.069)	ω	0.0007 (1.455)	ω	0.0005 (1.548)
α	0.203* (1.181)	α	0.178 (1.314)	α	0.387 (1.569)
β	-	β	0.607** (3.552)	β	0.437** (2.511)
δ	0.002 (1.324)	δ	0.0004 (1.017)	δ	0.0007 (1.248)

Panel B: Diagnostic tests on standardized residuals of models for three types of vessels

	Capesize	Panamax	Handymax
J-B normality test	1499 [0.00]	1852 [0.00]	1305 [0.00]
$\bar{R}^2$	0.249	0.225	0.261
AIC	-3.415	-3.459	-3.895
SBIC	-3.365	-3.383	-3.820
Q(20)	23.735 [0.254]	23.258 [0.276]	19.213 [0.508]
$Q^2(20)$	7.036 [0.99]	7.158 [0.99]	5.583 [0.99]
Persistence ($\alpha_i + \beta_i$)	0.203	0.785	0.824

See notes to Table 6.2.

It can be concluded that second-hand ship prices of different ship sizes tend to respond together and symmetrically to external shocks, and yet quite differently in the short run. It implies that there are common driving forces behind volatilities in different markets, but each market can also be influenced by its own factors, making the volatility in each segment move in its own way. The different nature of volatilities of each ship size can be manifested in the GARCH coefficients. The time-varying variation is shown and large changes in volatilities tend to occur around certain years over the period after 2003, resulting from large imbalances and shocks in the dry bulk market. The existence of volatility varying over different market conditions and the asymmetric volatility, however, cannot be found statistically.

6.2. An empirical analysis of relationships between second-hand ship prices and time charter rates

There are limited studies in the literature examining the formation of ship prices and relations between prices. Pioneering work was seen of Beenstock (1985), Strandnes (1984) and Beenstock and Vergottis (1993), which triggered later on a series of studies on this topic. Examples are Hale and Vanags (1992), Kavussanos(1996b, 1997) Glen(1997), Veenstra (1999) and Kavussanos and Alizadeh (2002b) among others.

It can be seen from previous studies that time charter rates tend to be the determinant of ship prices, including new-building prices, second hand prices and scrap prices and there seem to be significant cointegration relationships between time charter rates and second-hand ship prices for three different ship types of dry bulk carriers. Most of the previous research focused on the dry bulk market before 2000, while the dry bulk market has changed a lot since 2000, especially since 2003, when the market has recovered and run into an unexpected long booming period until September 2008, after which the market collapsed due to the financial crisis. A more volatile and speculative market may make the underlying mechanism shift in each sector of dry bulk market. The relationships between charter rates, including spot rates and time charter rates, and second-hand ship prices should be re-examined under the new market conditions.

The remainder of this part describes the methodology of examining relationships among variables, followed by the introduction of the data source and statistical properties, and the discussion of empirical results and findings.

6.2.1. Methodology

Cointegration test is used to investigate a long-run equilibrium relationship among variables. The first step in examining the cointegration relationship between second-hand ship prices and charter rates in different ship size markets, is to determine the order of integration of each price series using Augmented Dickey-Fuller (ADF,1981), Phillips and Perron (PP, 1988). Given a set of two I(1) series, the VECM (Johansen, 1988) is employed to make the estimation. The specification of a VECM model, shown as follows, can be seen in Appendix A.

$$\Delta X_t = \mu + \sum_{i=1}^{p-1} \Gamma_i \Delta X_{t-i} + \prod X_{t-1} + \varepsilon_t, \quad \varepsilon_t | \Omega_{t-1} \sim distr(0, H_t)$$

Here X_t is the 2×1 vector of log ship prices and log charter rates respectively. Δ denotes the first difference operator, ε_t is a 2×1 vector of error terms $(\varepsilon_{c,t}, \varepsilon_{p,t})'$, following an as-yet-unspecified conditional distribution with mean zero and time-varying covariance H_t. Γ_i and $\prod$ are coefficient matrices. The VECM specification contains information on both the short- and long-run adjustment to changes in X_t via the estimates of Γ_i and $\prod$ respectively.

If second-hand ship prices and charter rates are cointegrated, then causality must exist in at least one direction (Granger,1988). Granger causality can identify whether two variables move one after the other or contemporaneously. When they move contemporaneously, one provides no information for characterizing the other. If X causes Y, then changes in X should precede changes in Y, and vice versa.

6.2.2. Description of the data and the statistical properties

The data set consists of spot earnings, one-year time charter rates and three-year time charter rates, generally called charter rates in the freight market, together with second-hand ship prices in the ship market for dry bulk vessels. Prices for Panamax and Handymax vessels cover the period from Jan 1990 to Dec 2010, yielding a sample of 252 observations, and the sample period for Capesize vessels starts from Dec 1991 to Dec 2010 with 229 observations. Monthly charter rates for each ship size are all obtained from Clarkson Research Studies, and second-hand ship prices are from Clarkson Research Studies and the Baltic Exchange, as explained in Section 6.1. Trends of all these variables can be shown in Figures 6.3-6.5. Additionally, some structural variables are incorporated to measure their impacts on second-hand ship prices, including the US dollar index and the 6-month US$ London Interbank Offered Rate (LIBOR). Their data during the sample period from Jan 1990 to Dec 2010 are obtained from a futures company in shanghai and Clarkson Research Studies, respectively. The summary statistics of logarithmic variables during sample period are presented in Table 6.4.

Results of all price series in the freight market have already been discussed in Section 5.2, so they will not be explained here. The results of prices in the second-hand ship market reveal that during the sample period, the mean values of second-hand ship prices seem to be higher for larger vessels than smaller ones, as expected. Excess skewness and kurtosis are found for second-hand ship price series, supported by the J-B normality test of rejecting the hypothesis of normality (skewness=0, kurtosis=3) in all cases. The Ljung-Box Q(20) and $Q^2(20)$ statistics reject the null hypothesis of non-autocorrelation and non heteroskedasticity in all price series. The augmented Dickey-Fuller and Philips Perron unit root tests display that all variables are log-first difference stationary, and all have a unit root on the log-levels representation.

6.2.3. Empirical analysis

Cointegration test is made between charter rates and second-hand ship prices for three size bulk carriers during the sample period. A VECM model is employed to estimate parameters of each equation. All the results below are explained in economic ways, so as to figure out the interrelationships between charter rates and second-hand ship prices in the Capesize, Panamax and Handymax markets during the sample period.

6.2.3.1.Cointegration between second-hand ship prices and charter rates

Having identified that charter rates and ship prices in three ship size markets are all $I(1)$ variables, the Johansen (1988) procedure is employed, in order to test for cointegration in all cases. The Schwartz Bayesian Information Criterion (Schwarz, 1978), Akaike Information Criterion(AIC)(Akaike, 1973) and the LR test are used to determine the lag length in the models. The results for cointegration test are shown in Table 6.5 and the estimation results of the VECM models are reported in Table 6.6.

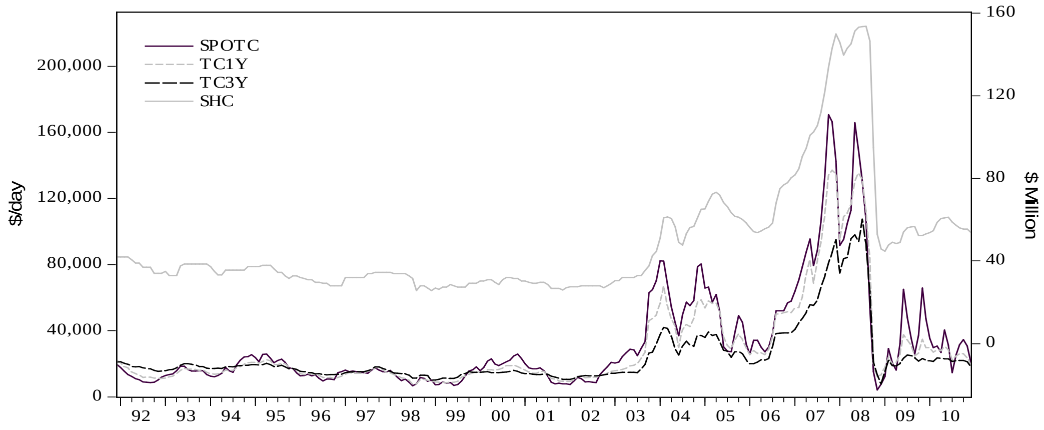

Figure 6.3: Second-hand ship prices and charter rates for Capsize vessels during Jan 1991 to Dec 2010.

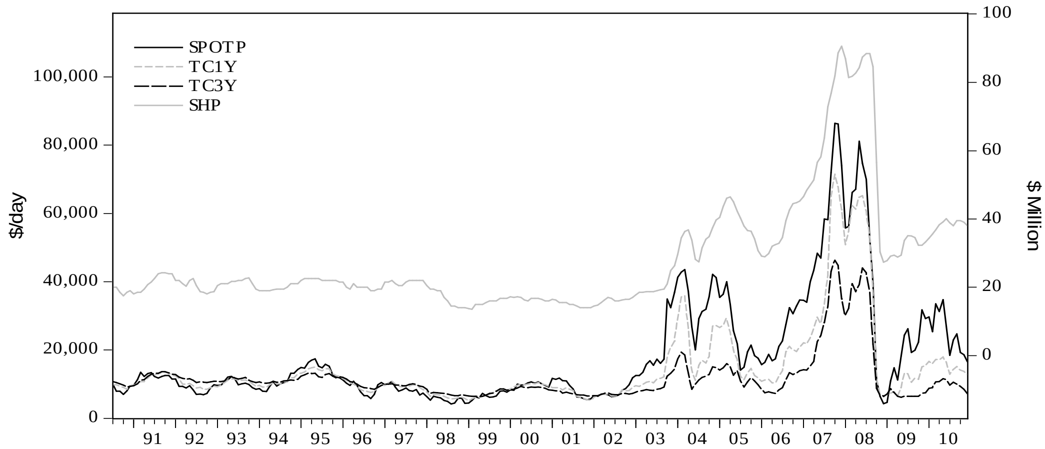

Figure 6.4: Second-hand ship prices and charter rates for Panamax vessels during Jan 1990 to Dec 2010.

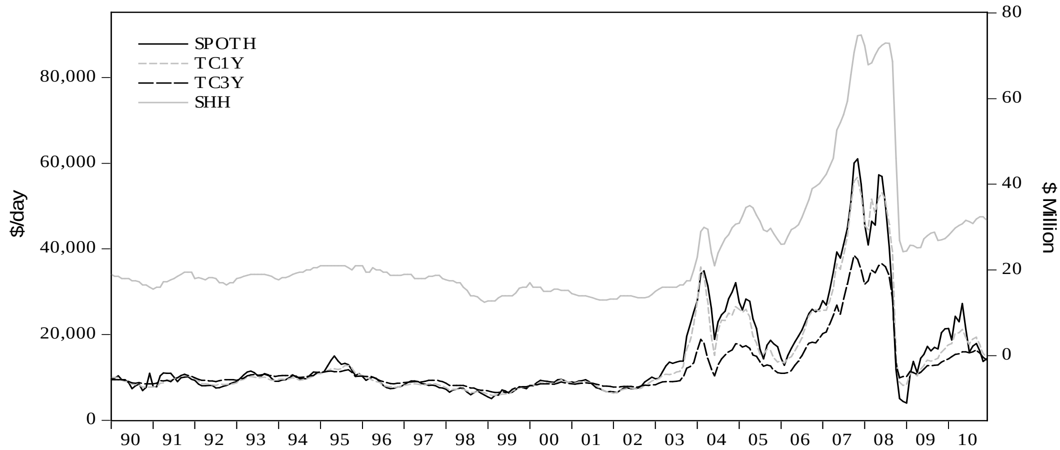

Figure 6.5: Second-hand ship prices and charter rates for Handymax vessels during Jan 1990 to Dec 2010.

Table 6.4: Descriptive statistics of logarithmic prices in the freight and second-hand ship markets for three types of vessels

	N	Mean	Median	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Q(20)	$Q^2(20)$	ADF(lags)	PP	ADF(lags)	PP
										Lev	Lev	1st diffs	1st diffs
The Capesize market													
Spot	229	10.035	9.886	0.772	0.624[0.00]	2.709 [0.26]	15.69[0.00]	1973.4	1637.2	-2.529(2)	-2.519(6)	-10.972(1)	-9.577(20)
TC1Y	229	9.987	9.770	0.678	1.012 0.00]	3.297[0.48]	38.89[0.00]	2058.6	2023.8	-2.437(9)	-1.649(0)	-4.727(9)	-9.656(12)
TC3Y	229	9.923	9.809	0.517	1.370[0.00]	4.553[0.00]	94.69[0.00]	1802.4	1772.7	-2.049(3)	-2.307(3)	-9.578(2)	-8.848(16)
SHC	229	3.760	3.572	0.453	1.228[0.00]	3.847[0.00]	64.38[0.00]	2882.3	2535.1	-1.972(1)	-1.576(5)	-8.447(0)	-8.202(1)
The Panamax market													
Spot	252	9.522	9.336	0.690	0.747[0.00]	2.824[0.64]	23.784[0.00]	1425.8	1461.3	-3.343(3)	-2.807(5)	-13.769(0)	-13.79(3)
TC1Y	252	9.397	9.266	0.541	1.402[0.00]	5.036[0.00]	126.09[0.00]	1406.1	1388.9	-3.362(1)	-2.739(5)	-9.574(1)	-9.313(3)
TC3Y	252	9.264	9.220	0.404	1.674[0.00]	6.453[0.00]	242.94[0.00]	1204.6	1200.9	-3.593(1)	-2.185(3)	-9.392(1)	-8.805(13)
SHP	252	3.208	3.068	0.452	1.171[0.00]	3.824[0.00]	64.76[0.00]	2980.3	2818.5	-1.808(1)	-1.549(6)	-9.54(0)	-9.469(3)
The Handymax market													
Spot	252	9.419	9.218	0.571	0.936[0.00]	3.130[0.54]	36.97[0.00]	2059.7	2058.6	-2.718(1)	-2.328(3)	-10.849(0)	-10.276(13)
TC1Y	252	9.388	9.181	0.540	1.210[0.00]	3.668[0.01]	66.19[0.00]	2334.4	2282.6	-2.496(1)	-1.927(3)	-8.933(0)	-8.236(16)
TC3Y	252	9.321	9.217	0.388	1.499[0.00]	4.933[0.00]	133.6[0.00]	2313	2267.2	-2.508(1)	-1.936(3)	-9.178(1)	-8.417(14)
SHH	252	3.074	2.938	0.423	1.289[0.00]	4.244[0.00]	86.02[0.00]	3018.5	2843.4	-1.865(1)	-1.488(4)	-9.338(0)	-8.961(9)
USDX	252	4.269	4.885	2.087	-0.203[0.19]	2.179[0.01]	8.808[0.01]	3017.5	3033.1	-1.971(1)	-1.629(3)	-10.36(1)	-10.96(4)
LIBOR	252	4.513	4.495	0.112	0.497[0.00]	2.833[0.59]	10.65[0.01]	2256.5	1869.3	-1.521(2)	-1.569(8)	-7.725(1)	-11.674(5)

Notes:

- All prices are transformed into logarithmic.
- SHC, SHP and SHH mean second-hand ship prices for Capesize, Panamax and Handymax vessels, respectively.
- N is the number of observations
- Q(20) and $Q^2(20)$ are the Ljung and Box (1978) Q statistics on the first 20 lags of the sample autocorrelation function of the raw series and of the squared series; these tests are distributed as $\chi^2(20)$ .The critical values are 37.57 and 31.41 for the 1% and 5% levels, respectively.
- Lev and 1st diffs refer to price series in log-levels and log-first differences, respectively. The 5% critical value for the ADF and PP tests is -2.869; the 1% critical value for the ADF and PP tests is -3.447.
- See other notes to Table 6.1.

Table 6.5: Johansen (1988) tests for the number of cointegrating vectors between charter rates and second-hand ship prices

	Lags	*Hypothesis (maximal)*		*Test statistic*	*Hypothesis (trace)*		*Test statistic*	*95% Critical values*		Cointegrating vector
		H_0	H_1	$\lambda_{\max}$	H_0	H_1	λ_{trace}	$\lambda_{\max}$	λ_{trace}	$\beta' = (1, \beta_1, \beta_2)$
The Capesize market										
SHC/Spot	2,9	$r = 0$	$r = 1$	26.46	$r = 0$	$r = 1$	31.48	15.89	20.26	(1,3.91,-0.766)
		$r \leq 1$	$r = 2$	5.02	$r \leq 1$	$r = 2$	5.02	9.16	9.16	
SHC/TC1Y	1,8,9	$r = 0$	$r = 1$	20.13	$r = 0$	$r = 1$	22.96	15.89	20.26	(1,4.14, -0.791)
		$r \leq 1$	$r = 2$	2.82	$r \leq 1$	$r = 2$	2.82	9.16	9.16	
SHC/TC3Y	1	$r = 0$	$r = 1$	13.85	$r = 0$	$r = 1$	16.59	15.89	20.26	-
		$r \leq 1$	$r = 2$	2.74	$r \leq 1$	$r = 2$	2.74	9.16	9.16	
The Panamax market										
SHP/Spot	3	$r = 0$	$r = 1$	22.52	$r = 0$	$r = 1$	26.65	15.89	20.26	(1,4.49,-0.810)
		$r \leq 1$	$r = 2$	4.12	$r \leq 1$	$r = 2$	4.12	9.16	9.16	
SHP/TC1Y	2	$r = 0$	$r = 1$	22.97	$r = 0$	$r = 1$	24.79	15.89	20.26	(1,7.83, -1.178)
		$r \leq 1$	$r = 2$	1.82	$r \leq 1$	$r = 2$	1.82	9.16	9.16	
SHP/TC3Y	1	$r = 0$	$r = 1$	12.55	$r = 0$	$r = 1$	13.85	15.89	20.26	-
		$r \leq 1$	$r = 2$	1.29	$r \leq 1$	$r = 2$	1.29	9.16	9.16	
The Handymax market										
SHH/Spot	2	$r = 0$	$r = 1$	36.95	$r = 0$	$r = 1$	41.86	15.89	20.26	(1,6.04,-0.969)
		$r \leq 1$	$r = 2$	4.91	$r \leq 1$	$r = 2$	4.91	9.16	9.16	
SHH/TC1Y	1	$r = 0$	$r = 1$	18.61	$r = 0$	$r = 1$	22.23	15.89	20.26	(1,6.81, -1.06)
		$r \leq 1$	$r = 2$	3.62	$r \leq 1$	$r = 2$	3.62	9.16	9.16	
SHH/TC3Y	2	$r = 0$	$r = 1$	10.85	$r = 0$	$r = 1$	13.35	15.89	20.26	-
		$r \leq 1$	$r = 2$	2.49	$r \leq 1$	$r = 2$	2.49	9.16	9.16	

Notes:

- Lags is the lag length of a VAR model; the lag length is determined using the SBIC (1978), AIC(1973) and LR tests. r represents the number of cointegrating vectors.
- $\lambda_{\max}(r, r+1) = -T\ln(1-\hat{\lambda}_{r+1})$ and $\lambda_{trace}(r) = -T\sum_{i=r+1}^{n}\ln(1-\hat{\lambda}_i)$ where $\hat{\lambda}_i$ are the estimated eigenvalues of the Π matrix in Eq.(1). Critical values are from Osterwald-Lenum(1992), Table1.
- Estimates of the coefficients in the cointegrating vector are normalized with respect to the coefficient of charter rates.
- The statistic for the parameter restrictions on the coefficients of the cointegrating vector is $-T[\ln(1-\hat{\lambda}_1^*) - \ln(1-\hat{\lambda}_1)]$ where $\hat{\lambda}_1*$ and $\hat{\lambda}_1$ denote the largest eigenvalues of the restricted and the unrestricted models, respectively. The statistic is distributed as χ^2 with degrees of freedom equal to the total number of restrictions minus the number of the just identifying restrictions, which equals the number of restrictions placed on the cointegrating vector.

Table 6.6: Estimates of the VECM model in the three markets

$$\Delta P_t = \sum_{i=1}^{p-1} \alpha_{1,i} \Delta P_{t-i} + \sum_{i=1}^{p-1} \beta_{1,i} \Delta TC_{t-i} + \gamma_1 Z_{t-1} + \varepsilon_{1,t}$$

$$\Delta TC_t = \sum_{i=1}^{p-1} \alpha_{2,i} \Delta P_{t-i} + \sum_{i=1}^{p-1} \beta_{2,i} \Delta TC_{t-i} + \gamma_2 Z_{t-1} + \varepsilon_{2,t}$$

Panel A: VECM model estimates

	Capesize					Panamax				Handymax			
	ΔSH_t	ΔSP_t	ΔSH_t	$\Delta TC1Y_t$		ΔSH_t	ΔSP_t	ΔSH_t	$\Delta TC1Y_t$	ΔSH_t	ΔSP_t	ΔSH_t	$\Delta TC1Y_t$
$\gamma_{j,}\ j=1,2$	-0.039** (-3.146)	0.122* (1.798)	-0.062** (-3.580)	0.030 (0.563)	$\gamma_{j,}\ j=1,2$	-0.055** (-3.664)	0.035 (0.662)	-0.010 (-1.016)	0.095** (3.432)	-0.042* (-1.909)	0.095 (1.171)	-0.023* (-1.839)	0.039 (1.546)
$\alpha_{j,1}, j=1,2$	0.239 (1.396)	-	-	-	$\alpha_{j,1}, j=1,2$	0.355** (2.878)	0.451* (1.932)	0.158 (1.561)	-	0.471** (2.919)	0.912** (2.568)	-	-0.160 (-1.059)
$\alpha_{j,2}, j=1,2$	-	-			$\alpha_{j,2}, j=1,2$	-0.288** (-2.834)	-	-0.098* (-1.884)	0.172 (1.128)	-0.249** (-2.336)	-0.386 (-1.274)		
$\alpha_{j,9}, j=1,2$	-	-	-0.157** (-2.669)	-0.256 (-1.387)	$\alpha_{j,3}, j=1,2$	-	-0.733** (-3.662)						
$\beta_{j,1}, j=1,2$	0.103** (3.306)	0.443** (3.045)	0.298** (13.086)	0.473** (7.532)	$\beta_{j,1}, j=1,2$	0.139** (3.69)	0.221** (2.983)	0.308** (5.358)	0.575** (9.141)	0.075** (2.502)	0.203* (1.869)	0.382** (13.355)	0.604** (7.026)
$\beta_{j,2}, j=1,2$	-	-0.169 (-1.628)			$\beta_{j,2}, j=1,2$	-	-0.093 (-1.219)	-	-0.152* (-1.945)	-	-		
$\beta_{j,8}, j=1,2$			-0.063** (-3.019)	-0.304** (-4.826)	$\beta_{j,3}, j=1,2$	0.038 (1.336)	0.128* (1.766)						
$\beta_{j,9}, j=1,2$	0.026 (1.284)	0.198** (1.983)	0.122** (4.476)	0.476** (5.265)									

Causality test

$\Delta P_t \rightarrow \Delta TC_t$	0.548	[0.91]	2.286	[0.51]	$\Delta P_t \rightarrow \Delta TC_t$	18.31	[0.00]	1.29	[0.52]	20.40	[0.00]	1.12	[0.29]
$\Delta TC_t \rightarrow \Delta P_t$	31.487	[0.00]	62.38	[0.00]	$\Delta TC_t \rightarrow \Delta P_t$	44.33	[0.00]	136.08	[0.00]	7.53	[0.02]	79.62	[0.00]

Table 6.6: Continued

Panel B: Residual diagnostics													
J-B test	2018 [0.00]	264 [0.00]	720 [0.00]	4347 [0.00]	J-B test	1394 [0.00]	1208 [0.00]	720 [0.00]	2379 [0.00]	2198 [0.00]	1791 [0.00]	3677 [0.00]	19740 [0.00]
$Q(20)$	13.49 [0.86]	30.52 [0.07]	18.68 [0.54]	22.16 [0.33]	$Q(20)$	16.53 [0.68]	22.43 [0.11]	23.53 [0.31]	32.25 [0.02]	17.45 [0.62]	26.88 [0.14]	18.71 [0.54]	31.19 [0.05]
$Q^2(20)$	89.16 [0.00]	244.86 [0.00]	8.30 [0.99]	6.34 [0.99]	$Q^2(20)$	56.53 [0.00]	14.64 [0.79]	44.32 [0.00]	23.03 [0.29]	64.77 [0.00]	87.53 [0.00]	16.43 [0.69]	3.68 [0.99]
ARCH(20)	93.19 [0.00]	101.07 [0.00]	9.21 [0.98]	5.94 [0.99]	ARCH(20)	54.37 [0.00]	12.14 [0.91]	41.99 [0.00]	16.95 [0.66]	50.11 [0.00]	80.35 [0.00]	12.41 [0.90]	3.52 [0.99]
$\bar{R}^2$	0.42	0.18	0.59	0.31	$\bar{R}^2$	0.48	0.13	0.55	0.25	0.35	0.18	0.47	0.26

Notes:

- All variables are transformed in natural logarithms
- Δ means the first difference; P denotes ship prices generally; TC time charter rates generally; ΔSH_t means the first difference of second hand ship price at time t; ΔSP_t the first difference of spot rate at time t; $\Delta TC1Y_t$ the first difference of one-year time charter rate at time t.
- ** and * indicate significance at the 5% and 10% levels, respectively
- Figures in parentheses (.) and in squared brackets [·] indicate t-statistics and exact significance levels, respectively
- J-B Normality is the Jarque and Bera(1980) normality test, with probability values in square brackets
- $Q(20)$ and $Q^2(20)$ are the Ljung and Box (1978) tests for 20th order serial correlation and heteroskedasticity in the standardized residuals and in the standardized squared residuals, respectively.
- ARCH(20) is the Engle's(1982) F test for Autoregressive Conditional Heteroskedasticity.

The examination of the cointegration relationship between second-hand prices and charter rates is all carried out during the sample period from Jan 1990 to Dec 2010 for Panamax and Handymax, and three pairs for Capesize vessels are estimated during the sample period from Dec 1991 to Dec 2010. The estimated $\lambda_{\max}$ and λ_{trace} statistics in Table 6.5 show that charter rates and second-hand ship prices are cointegrated at the conventional significance levels in all cases, with the exception of the pair between three-year time charter rates and second-hand ship prices. Cointegration statistics reveal that three-year time-charter prices and second-hand ship prices are not cointegrated in three ship size markets.

In order to provide some insight into short-run parameters of both equations, we estimate the models using seemingly unrelated regressions estimation (SURE). The SURE method is used because a gain in efficiency can occur when a particular equation is considered as part of the system, if models are formulated with constraints across both equations. The residual diagnostics tests, presented also in Table 6.6 indicate the existence of heteroskedasticity for residuals in some equations, therefore, the standard errors and t statistics of the estimated coefficients are adjusted by White (1980) heteroskedasticity correlation.

Turning next to the estimates of models in Table 6.6. In the Capesize market, results of cointegration relationship between the spot earnings and second-hand ship prices indicate that the coefficient of the error correction term (ECT), which is the difference between the spot earnings and second-hand ship prices, of the mean equation of ship prices is significant at the 5% significance level, and the error correction coefficient of the spot rate equation is significant at the 10% significance level with opposite signs. Results of the pair between one-year time charter rates and ship prices reveal that the error correction coefficient of the ship price equation is statistically significant, while the ECT of the time-charter rate equation is not significant at the conventional significance levels.

In the Panamax market, for the pair between the spot earnings and ship prices, the error correction coefficient in the ship price equation is significant at the 5% significance level, while that in the spot rate equation is not significant statistically. For the other pair, only the error correction coefficient of the mean equation of one-year time charter rates is significant at 5% significance level.

In the Handymax market, the error correction term parameter of the spot rate equation and that of one-year time-charter rate equation are not significant at conventional levels, while the ECT coefficients of second-hand ship price equations are all significant at the 10% level.

In most cases with the exception of the pair between ship prices and one-year time-charter rates for Panamax, the ECT parameters in the ship price equations are all significant statistically. It implies that the second-hand ship prices respond to the previous deviation from the long-run equilibrium and eliminate the disequilibrium, while charter rates remain unresponsive and seem not to do the correction to remove the disequilibrium in most cases.

More rigorous investigation of interactions between the variables can be obtained by performing Granger causality tests, which are also presented in Table 6.6 and the simplified picture is presented in Figure 6.6. Significant causality is found from charter rates to second-hand prices for three size bulk carriers in all cases. The Granger causality test from second-hand prices to charter rates, however, shows mixed results. Second-hand ship prices granger cause one-year time-charter rates for Capesize vessels, and the causality is seen from second-hand ship prices to spot rates for Panamax and Handymax.

Findings regarding the significance of coefficients of the error correction term in all equations and findings regarding the granger causality test may be explained by the economic mechanism in the second-hand market. The second-hand ship market is the one trading in the existing ships. Since theoretically ship prices are determined through the discounted present value of the expected earnings as shown in Kavussanos and Alizadeh (2002b), the second-hand ship prices are primarily influenced by charter rates. Peaks and troughs in the freight market are transmitted into the sale and purchase market, as shown in Stopford (2009).During the period of the freight boom, the cash inflow from the freight market provides capital for ship-owners to acquire ships in the second-hand market to meet the spot demand for sea transport. The increasing demand for second-hand ships will lead to the subsequent rise in second-hand ship prices. During the period of the freight depression, sustained low charter rates and tight credit policies create a negative net cashflow which becomes progressively greater. Ship-owners short of cash are forced to sell ships at distress prices. Subsequently, second-hand ship prices respond to changes of prices in the freight market and charter rates are expected to Granger cause second-hand prices in all cases.

Besides charter rates, shipbrokers argue that there are other two primary factors, i.e. shipowners' cashflow pressure and the expectations of the future market, which are exerting substantial impact on second-hand ship prices. The heterogeneous expectations on the future market and diverse cashflow pressure will make second-hand prices and charter rates differ in their ability to respond to new market information. In this case, second-hand ship prices will not correct the disequilibrium created from previous periods' deviations, as being the case of the pair between second-hand ship prices and one-year time-charter rates in the Panamax market.

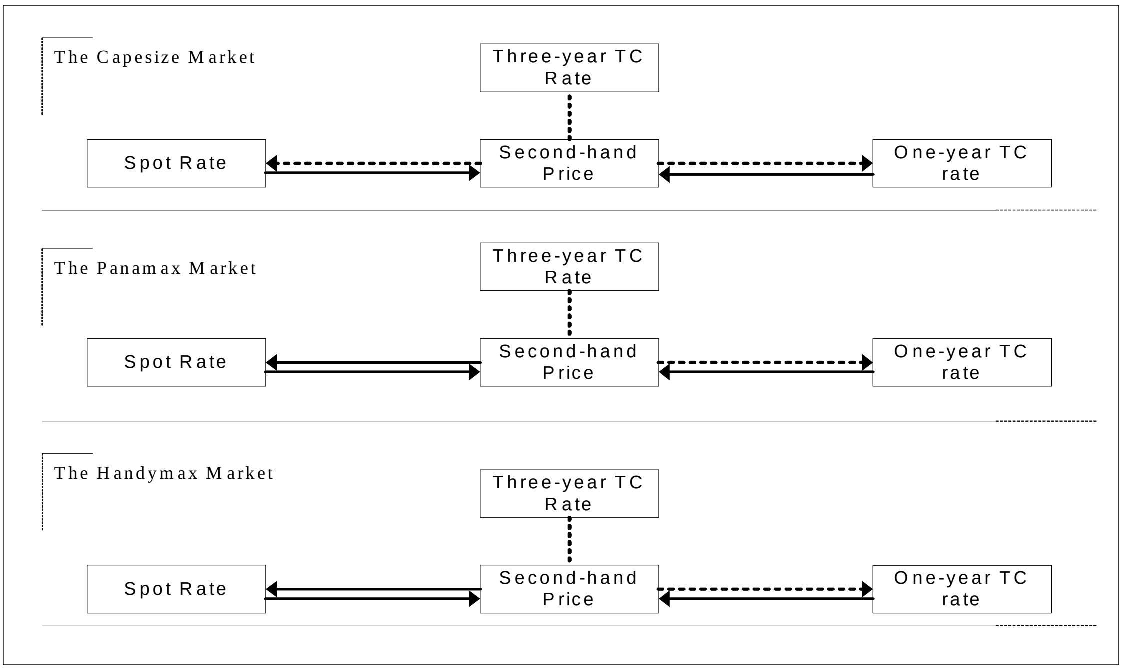

Figure 6.6: Relations between ship prices and charter rates in three markets
Notes: the solid line with arrow denotes significant causality relationship; the dash line with arrow indicates insignificant causality relationship; and the dotted line without arrow shows no cointegration relationship between variables.

6.2.3.2. Impact of macroeconomic indicators on second-hand ship prices

As discussed above, charter rates are the main determinant of second-hand ship prices, which are assumed to be a function of a vessel's revenues. Therefore, it is assumed that the higher the time charter rate, the higher the ship's profitability and as a result, the higher its second-hand value. Apart from charter rates, there are other factors which may have impacts on second-hand ship prices.

Exchange rate

Second-hand ship prices are quoted in US dollars, so they may be influenced by any changes in the value of the US dollar. The US Dollar Index, as introduced in Chapter 4, is an index of measuring the US dollar against a basket of foreign currencies, whose impact on the second-hand ship values will be investigated.

Interest rate

Interest rate is used to measure the cost of capital of financing ships. If interest rate is increased, the cost of capital will be raised and ship-owners' acquisition becomes more expensive. In this case, the liquidity of most ship-owners is lowered and the demand for second-hand ships may be limited. So interest rate may have a negative effect on second-hand ship prices. In this part, the average 6-month US$ LIBOR rate is used to measure its impact on second-hand ship prices.

In order to examine impacts of these economic indicators on the second-hand ship market, these exogenous variables are included into the VECM of two pairs for each ship size. Before adding these variables into the model, their stationarity should be checked. Results in Table 6.4 reveal that these variables contain one unit root on log-levels, but become stationary on logarithmic first differences. Furthermore, for the purpose of forecasting ship prices, the lagged first differences of these economic indicators are included into the VEC model, called the VECM-X model. Results of VECM-X models in three markets can be found in Table 6.7.

As expected, the coefficients of the US dollar index in the second-hand ship equation are negative in all cases. Because the sale and purchase of second-hand ships are consummated in the US dollar, a general appreciation of the dollar relative to other currencies tends to lower second-hand ship prices. However, the parameter of the US dollar index is only significant for Capesize vessels at the 10% significance level and it is not for Panamax and Handymax vessels. Larger vessels require more capital than smaller ones, the appreciation or depreciation of the US dollar, therefore, might have a larger effect on Capesize vessels than the other two types of ships.

The LIBOR of the second-hand ship equation is found to be negative in all cases as well and it can be argued that changes in the interest rate may have a negative impact on the second-hand ship values. However, the negative parameter of the LIBOR in the second-hand price equation is only significant at the 10% significance level for the pair between second-hand prices and spot rates for three types of vessels, while it is not for the pair between second-hand prices and one-year time-charter rates of each ship size. As a consequence, no convincing evidence is observed regarding the effect of interest rate on second-hand ship prices. Furthermore, in reality, there are diverse financing sources and schemes, as well as different investment motives, therefore, an increase or a decrease in the cost of borrowing money from banks may not have a substantial impact on ship-owners' investment decisions.

Table 6.7: Estimates of the VECM-X model in the three markets

$$\Delta P_t = \sum_{i=1}^{p-1} \alpha_{1,i} \Delta P_{t-i} + \sum_{i=1}^{p-1} \beta_{1,i} \Delta TC_{t-i} + \gamma_1 Z_{t-1} + \varepsilon_{1,t}$$

$$\Delta TC_t = \sum_{i=1}^{p-1} \alpha_{2,i} \Delta P_{t-i} + \sum_{i=1}^{p-1} \beta_{2,i} \Delta TC_{t-i} + \gamma_2 Z_{t-1} + \varepsilon_{2,t}$$

Panel A: VECM model estimates

	Capesize			
	ΔSH_t	ΔSP_t	ΔSH_t	$\Delta TC1Y_t$
$\gamma_j, j=1,2$	-0.039** (-3.00)	0.113** (1.95)	-0.062** (-3.580)	0.030 (0.563)
$\alpha_{j,1}, j=1,2$	0.235** (3.169)	-0.269 (0.83)	-	-
$\alpha_{j,2}, j=1,2$	0.019 (0.28)	0.162 (0.54)		
$\alpha_{j,8}, j=1,2$			-0.031 (-0.34)	0.142 (0.69)
$\alpha_{j,9}, j=1,2$	0.002 (0.03)	0.223 (0.88)	-0.157** (-2.669)	-0.256 (-1.387)
$\beta_{j,1}, j=1,2$	0.097** (5.47)	0.428** (5.54)	0.298** (13.086)	0.473** (7.532)
$\beta_{j,2}, j=1,2$	0.003 (0.16)	-0.114 (-1.49)		
$\beta_{j,8}, j=1,2$			-0.063** (-3.019)	-0.304** (-4.826)
$\beta_{j,9}, j=1,2$	0.025** (1.49)	0.171** (2.34)	0.122** (4.476)	0.476** (5.265)
$\Delta usdx_{t-1}$	-0.294* (-1.84)	-1.411** (-2.02)	-0.223* (-1.734)	-1.146** (-2.459)
$\Delta libor_{t-1}$	-0.106** (-2.52)	-0.513** (-2.71)	-0.049 (-1.309)	-0.105 (-0.922)

	Panamax				Handymax			
	ΔSH_t	ΔSP_t	ΔSH_t	$\Delta TC1Y_t$	ΔSH_t	ΔSP_t	ΔSH_t	$\Delta TC1Y_t$
$\gamma_j, j=1,2$	-0.058** (-3.79)	0.034 (0.64)	-0.010 (-1.016)	0.095** (3.432)	-0.045** (-3.255)	0.081** (2.18)	-0.023* (-1.839)	0.039 (1.546)
$\alpha_{j,1}, j=1,2$	0.357** (5.04)	0.337 (1.38)	0.158 (1.561)	-	0.442** (5.759)	0.844** (4.11)	-	-0.160 (-1.059)
$\alpha_{j,2}, j=1,2$	-0.251** (-3.44)	0.095 (0.37)	-0.098* (-1.884)	0.172 (1.128)	-0.248** (-3.36)	-0.266 (-1.346)		
$\alpha_{j,3}, j=1,2$	-0.004 (-0.06)	-0.765** (-3.63)						
$\beta_{j,1}, j=1,2$	0.130** (6.14)	0.190** (2.59)	0.308** (5.358)	0.575** (9.141)	0.073* (2.648)	0.201** (2.717)	0.382** (13.355)	0.604** (7.026)
$\beta_{j,2}, j=1,2$	-0.003 (-0.119)	-0.049 (-0.63)	-	-0.152* (-1.945)	0.024 (0.845)	-0.009 (-0.12)		
$\beta_{j,3}, j=1,2$	0.034 (1.51)	0.119 (1.55)						
$\Delta usdx_{t-1}$	-0.212 (-1.38)	-1.658** (-3.13)	-0.168 (-1.195)	-1.208** (-3.186)	-0.204 (-1.329)	-0.652 (-1.59)	-0.175 (-1.26)	-0.573 (-2.073)
$\Delta libor_{t-1}$	-0.084* (-1.74)	-0.199 (-1.40)	-0.033 (-0.858)	-0.049 (-0.485)	-0.089** (-2.19)	-0.337** (-3.09)	-0.031 (-0.86)	-0.135 (-1.233)

Table 6.7: Continued

Panel B: Residual diagnostics

J-B test	2018 [0.00]	264 [0.00]	720 [0.00]	4347 [0.00]	J-B test	1394 [0.00]	1208 [0.00]	720 [0.00]	2379 [0.00]	2198 [0.00]	1791 [0.00]	3677 [0.00]	19740 [0.00]
$Q(20)$	13.49 [0.86]	30.52 [0.07]	18.68 [0.54]	22.16 [0.33]	$Q(20)$	16.53 [0.68]	22.43 [0.11]	23.53 [0.31]	32.25 [0.02]	17.45 [0.62]	26.88 [0.14]	18.71 [0.54]	31.19 [0.05]
$Q^2(20)$	89.16 [0.00]	244.86 [0.00]	8.30 [0.99]	6.34 [0.99]	$Q^2(20)$	56.53 [0.00]	14.64 [0.79]	44.32 [0.00]	23.03 [0.29]	64.77 [0.00]	87.53 [0.00]	16.43 [0.69]	3.68 [0.99]
ARCH(20)	93.19 [0.00]	101.07 [0.00]	9.21 [0.98]	5.94 [0.99]	ARCH(20)	54.37 [0.00]	12.14 [0.91]	41.99 [0.00]	16.95 [0.66]	50.11 [0.00]	80.35 [0.00]	12.41 [0.90]	3.52 [0.99]
$\overline{R}^2$	0.42	0.18	0.59	0.31	$\overline{R}^2$	0.48	0.13	0.55	0.25	0.35	0.18	0.47	0.26

Notes:

- All variables are transformed in natural logarithms
- Δ means the first difference; P denotes ship prices generally; TC time charter rates generally; ΔSH_t means the first difference of second hand ship price at time t; ΔSP_t the first difference of spot rate at time t; $\Delta TC1Y_t$ the first difference of one-year time charter rate at time t.
- ** and * indicate significance at the 5% and 10% levels, respectively
- Figures in parentheses (.) and in squared brackets [·] indicate t -statistics and exact significance levels, respectively
- J-B Normality is the Jarque and Bera(1980) normality test, with probability values in square brackets
- $Q(20)$ and $Q^2(20)$ are the Ljung and Box (1978) tests for 20^{th} order serial correlation and heteroskedasticity in the standardized residuals and in the standardized squared residuals, respectively.
- ARCH(20) is the Engle's(1982) F test for Autoregressive Conditional Heteroskedasticity.

6.3. Relationships between prices in the second-hand, the new-building, the scrap and the freight markets

Relationships between prices in the newbuilding, the second-hand, the scrap and the freight markets have already been discussed in Section 5.3. In this part, the US dollar index and LIBOR rate are added as exogenous variables, and three-year time charter rates are chosen to be included into a VAR-X model. Because the inclusion of three year time charter rates can provide the lower value of the Schwarz information criterion of the model and the higher value of the determination coefficient of the second-hand ship equation in the model. Table 6.8 reports all the results.

Several findings regarding second-hand ship prices may be obtained from the results. At first, results reveal that changes in second-hand prices are significantly influenced by changes in scrap prices at the 10% significance level for all types of vessels. Furthermore, a significant effect can be seen from new-building prices to second-hand prices at the 10% significance level for Capesize and Panamax, while the effect is not statistically significant for Handymax. These results can be explained from two aspects.

McConville (1998) argues that the second-hand price is usually limited by the price of a new ship and the price of a scrap vessel.

On the one hand, the new-building price usually poses a constraint on the upper limit, so we can find the significantly positive impact of newbuilding prices on second-hand prices for Capesize and Panamax. However, there are exceptions during the strong freight market when ship-owners pay in excess of new-building prices to secure tonnage in time to provide shipping services. Examples are seen in 2007 and in the first nine months of 2008 for the Capesize, in most of the time from 2004 to 2010 for the Panamax, and in most of the time from 2004 to 2008 for the Handymax. During the booms, the second-hand ship price, therefore, is more volatile and responds to the market information more quickly than the price of a new-building vessel, which always has to be built for around two years. In this case, second-hand prices are sometimes, little influenced by new-building ones.

On the other hand, the scrap price usually poses a constraint on the lower limit of the second-hand price. The scrap value is the residue value that ship-owners have to take into account when they estimate the long-term investment returns of vessels during their operation life. As a result, the scrapping vessel price is found to have a significant impact on the second-hand vessel price.

Secondly, results indicate that second-hand prices seem not to have an impact on the movement of new-building prices for all types of dry bulk vessels. This finding is consistent with the argument in Stopford (2009), who states that the new-building market is a relatively separate one segment, driven by a lot of factors out of the shipping market.

Finally, three-year time charter rates are expected to have a large positive impact on the determination of second-hand ship prices as expected. It implies that second-hand prices are primarily market driven and the demand for second-hand vessels reflects the anticipated future trading environment, rather than present market conditions.

The US dollar index is found to be negative in all cases, while it is statistically significant only for Capesize vessels and it is not significant for the other two types. The findings of the US dollar index in the VAR-X model keep consistent with the results in Table 6.7. The LIBOR is insignificant in the second-hand price equation for three types of vessels.

Table 6.8: Relationship between new-building prices, second-hand prices and scrap prices for each size (1990.01-2010.12)

	Capesize[!]				Panamax				Handymax			
	ΔNB_t	ΔSH_t	ΔSC_t	$\Delta TC3Y_t$	ΔNB_t	ΔSH_t	ΔSC_t	$\Delta TC3Y_t$	ΔNB_t	ΔSH_t	ΔSC_t	$\Delta TC3Y_t$
ΔNB_{t-1}	0.274**	0.188*	0.373	0.42	0.289**	0.201*	0.143	0.073	0.256**	-0.056	0.09	-0.062
	(4.26)	(1.742)	(1.606)	(1.45)	(4.889)	(1.94)	(0.648)	(0.29)	(4.25)	(-0.489)	(0.358)	(-0.35)
ΔSH_{t-1}	0.013	0.044	-0.223*	-0.028	-0.006	0.160**	-0.237**	-0.17`	-0.005	0.004	-0.032	-0.224**
	(0.355)	(0.728)	(-1.737)	(-0.17)	(-0.211)	(3.243)	(-2.25)	(-1.453)	(-0.143)	(0.073)	(-0.199)	(-2.094)
ΔSC_{t-1}	0.046*	0.169**	-0.196**	-0.022	0.007	0.192**	-0.251**	-0.065	0.014	0.057*	-0.198**	-0.014
	(2.17)	(4.669)	(-2.52)	(-0.239)	(0.391)	(5.724)	(-3.51)	(-0.818)	(0.81)	(1.779)	(-2.55)	(-0.293)
$\Delta TC3Y_{t-1}$	0.015	0.283**	0.160**	0.356**	0.104**	0.311**	0.333**	0.521**	0.129**	0.574**	0.141	0.620**
	(1.14)	(8.764)	(2.314)	(4.14)	(6.022)	(10.30)	(5.187)	(7.238)	(4.236)	(9.908)	(1.021)	(6.683)
$\Delta usdx_{t-1}$	-0.067	-0.530**	-0.761**	-1.61**	-0.038	-0.179	-0.318	-0.697**	-0.024	-0.11	-0.726**	-0.371*
	(-0.789)	(-3.698)	(-2.475)	(-4.22)	(-0.533)	(-1.418)	(-1.179)	(-2.31)	(-0.364)	(-0.865)	(-2.394)	(-1.86)
$\Delta libor_{t-1}$	0.073**	-0.002	-0.159*	-0.049	0.041**	-0.017	-0.140*	-0.097	0.064**	0.015	-0.214**	-0.055
	(3.16)	(0.51)	(-1.902)	(-0.477)	(2.051)	(0.473)	(-1.86)	(-1.153)	(3.39)	(0.408)	(-2.488)	(-0.973)
$Q(20)$	26.09	21.92	16.29	33.63	19.936	36.92	21.09	37.03	24.44	15.25	26.95	19.62
	[0.15]	[0.345]	[0.69]	[0.03]	[0.46]	[0.01]	[0.39]	[0.01]	[0.22]	[0.76]	[0.137]	[0.482]
$Q^2(20)$	24.25	1.66	2.189	55.25	32.843	12.94	4.439	63.25	28.123	10.29	16.292	2.40
	[0.23]	[1.00]	[1.00]	[0.00]	[0.04]	[0.93]	[1.00]	[0.00]	[0.11]	[0.96]	[0.69]	[0.99]
$\overline{R}^2$	0.186	0.599	0.058	0.22	0.318	0.642	0.107	0.237	0.313	0.561	0.057	0.27

Notes:

- All variables are transformed in natural logarithms
- ΔNB_t means the first difference of logarithmic new-building ship prices, ΔSH_t the first difference of logarithmic second-hand prices, ΔSC_t the first difference of logarithmic scrap prices.
- ! denotes that the sample period for the Capesize vessels ranges from Jan 1991 to Dec 2010.
- ** and * indicate significance at the 5% and 10% levels, respectively.
- Figures in braces (.) indicate t-statistics
- $Q(20)$ and $Q^2(20)$ are the Ljung and Box (1978) tests for 20th order serial correlation and heteroskedasticity in the standardized residuals and in the standardized squared residuals, respectively.

6.4. Forecasts

As introduced in previous sections, the sample period for Capesize is from Dec 1991 to Dec 2010, while that for the other two types of bulk vessels runs from Jan 1990 to Dec 2010. For estimation and forecast purposes, the data are split into an in-sample estimation set and an out-of sample forecast set. Various forecasting models are estimated over the whole period from Jan 1990 to June 2009 for Panamax and Handymax, and over the period from Dec 1991 to June 2009 for Capesize. The period from July 2009 to Dec 2010, is then utilized to evaluate the independent out-of-sample N-period ahead of forecasts.

The Schwarz Bayesian Information Criterion (SBC; Schwarz, 1978) and the coefficient of determination ($\bar{R}^2$) are utilized to select charter rates in forecasting models. The VAR model with three-year time charter rates demonstrates the highest coefficient of determination and the lowest value of Schwarz criterion for each ship size. Hence, the VAR model includes second-hand ship prices, new-building, scrap prices and three-year time-charter rates. For the VECM model, results in Section 6.2 indicate that no cointegration relationship exists between second-hand ship prices and three-year time charter rates, the VECM model is, therefore, constructed for the pair between second-hand ship prices and one-year time charter rates with better values of determination and Schwarz criterion than those in the VECM model of the pair between second-hand ship prices and spot rates.

The lagged exogenous variables including the US dollar index and the LIBOR, are selected based on the criterion of minimizing SBC and improving the coefficients of determination of equations. By some empirical tests, the lagged US dollar index is chosen to be included into the ARMA, the VECM and the VAR models for Capesize vessels, while no exogenous variables are incorporated into various forecasting models for Panamax and Handymax vessels.

As a consequence, the forecasting models include the random walk the ARMA, the ARMA-X, the VECM, the VECM-X, the VAR and the VAR-X for Capesize vessels, and the random walk, ARMA, VECM and VAR for Panamax and Handymax vessels. Results of various forecasting models over the estimation period are reported in Tables 6.9-6.11. All forecasting models seem to be well specified, as indicated by relevant diagnostic tests for autocorrelation and heteroskedasticity. These alternative univariate and multivariate models, estimated over the initial estimation period, are used to generate independent forecasts of second-hand ship prices up to three steps ahead. As Batchelor et al (2007) point out that in order to avoid the bias induced by serially correlated overlapping forecast errors, the estimation period is recursively augmented by N-periods ahead every time (where N corresponds to the number of steps ahead). This method yields 18, 17 and 16 independent non-overlapping forecasts for one step, two steps and three-steps ahead, respectively.

The forecasting capabilities of various econometric methods are assessed for three types of vessels by using the following criteria including RMSE, MAE and Theil's inequality coefficient. The best forecasting model would be the one that produces the lowest RMSE, MAE, and Theil's.

Results of all estimates can be found in Table 6.12, based on which some findings are obtained

Table 6.9: Estimates of forecasting models for Capesize vessels during the period Dec 1991 to Jun 2009

	ARMA	ARMAX		VECM		VECM-X			VAR				VAR-X			
	ΔSHC_t	ΔSHC_t		ΔSHC_t	$\Delta TC1Y_t$	ΔSHC_t	$\Delta TC1Y_t$		ΔSHC_t	ΔNBC_t	ΔSCC_t	$\Delta TC3Y_t$	ΔSHC_t	ΔNBC_t	ΔSCC_t	$\Delta TC3Y_t$
ΔSHC_{t-1}	0.527** (2.69)	0.475** (2.64)	Z_{t-1}	-0.052** (-2.82)	0.087 (1.53)	-0.047** (-2.58)	0.106* (1.91)	ΔSHC_{t-1}	0.079 (1.259)	0.047 (1.29)	-0.258* (-1.949)	0.048 (0.284)	0.049 (0.813)	0.044 (1.20)	-0.298* (-2.261)	-0.037 (-0.229)
$\Delta USDX_{t-1}$		-0.798** (-3.579)	ΔSHC_{t-1}	-0.005 (-0.07)	-0.472** (-2.358)	-0.004 (-0.07)	-0.470** (-2.40)	ΔNBC_{t-1}	0.156 (1.325)	0.255** (3.72)	0.410 (1.652)	0.322 (1.007)	0.158 (1.39)	0.255** (3.71)	0.413* (1.686)	0.329 (1.07)
			ΔSHC_{t-9}	-0.143* (-1.71)	-0.406 (-1.558)	-0.137* (-1.65)	-0.382 (-1.495)	ΔSCC_{t-1}	0.187** (4.997)	0.030 (1.35)	-0.166** (-2.108)	0.029 (0.281)	0.173** (4.778)	0.028 (1.28)	-0.184** (-2.358)	-0.011 (-0.112)
			$\Delta TC1Y_{t-1}$	0.313** (11.30)	0.629** (7.336)	0.300** (10.69)	0.573** (6.672)	$\Delta TC3Y_{t-1}$	0.283** (8.216)	0.014 (0.693)	0.194** (2.676)	0.371** (3.956)	0.278** (8.363)	0.013 (0.668)	0.188** (2.622)	0.357** (3.971)
			$\Delta TC1Y_{t-9}$	0.074** (2.14)	0.453** (4.214)	0.07** (2.04)	0.435** (4.129)	$\Delta USDX_{t-1}$					-0.596** (-3.949)	-0.061 (-0.669)	-0.808** (-2.483)	-1.753** (-4.297)
			$\Delta USDX_{t-1}$			-0.362** (-2.16)	-1.598** (-3.133)									
$\overline{R}^2$	0.275	0.326	$\overline{R}^2$	0.586	0.232	0.593	0.265	$\overline{R}^2$	0.587	0.137	0.033	0.161	0.614	0.137	0.056	0.227
AIC	-2.852	-2.919	AIC	-3.348	-1.086	-3.361	-1.126	AIC	-3.388	-4.464	-1.894	-1.386	-3.452	-4.457	-1.914	-1.463
SC	-2.836	-2.888	SC	-3.265	-1.004	-3.265	-1.027	SC	-3.324	-4.400	-1.830	-1.322	-3.372	-4.377	-1.834	-1.383
$Q(20)$	14.568 [0.801]	12.858 [0.88]	$Q(20)$	13.695 [0.84]	29.28 [0.08]	11.26 [0.775]	27.68 [0.117]	$Q(20)$	26.22 [0.159]	27.87 [0.11]	11.39 [0.93]	34.77 [0.05]	23.39 [0.27]	27.87 [0.11]	11.56 [0.93]	30.76 [0.06]
$Q^2(20)$	59.99 [0.00]	58.19 [0.00]	$Q^2(20)$	3.54 [0.99]	11.37 [0.95]	3.62 [0.999]	7.16 [0.996]	$Q^2(20)$	8.49 [0.98]	19.20 [0.51]	3.07 [0.99]	57.35 [0.00]	4.94 [0.99]	19.20 [0.51]	3.04 [0.99]	49.38 [0.00]

Notes:

- All the series are measured in logarithmic first differences. ΔSHC_t, ΔNBC_t, $\Delta TC1Y_t$, $\Delta TC1Y_t$ and $\Delta TC3Y_t$ mean logarithmic first differences of second-hand prices, new-building, scrap prices, one-year and three-year timecharter prices for Capesize; $\Delta USDX_{t-1}$ denotes logarithmic means the logarithmic first difference of monthly US Dollar index;
- Figures in parenthesis (·) means t-statistics, adjusted using the White(1980) heteroskedasticity consistent variance-covariance matrix. * and ** denote significance at the 10% and 5% levels, respectively. Figures in square brackets [·] indicate exact significance levels
- Q(20) and $Q^2(20)$ are the Ljung and Box (1978) Q statistics on the first 20 lags of the sample autocorrelation function of the raw series and of the squared series; these tests are distributed as $\chi^2(20)$. The critical values are 37.56 and 31.41 for the 1% and 5% levels, respectively

Table 6.10: Estimates of forecasting models for Panamax vessels during the period Jan 1990 to Jun 2009

	ARMA		VECM			VAR			
	ΔSHP_t		ΔSHP_t	$\Delta TC1Y_t$		ΔSHP_t	ΔSHP_t	ΔSCP_t	$\Delta TC3Y_t$
ΔSHP_{t-1}	0.647** (2.90)	Z_{t-1}	-0.002 (-0.22)	0.116** (3.87)	ΔSHP_{t-1}	0.151** (2.96)	0.008 (0.264)	-0.282** (-2.62)	-0.189 (-1.05)
ΔSHP_{t-2}	-0.201* (-1.932)	ΔSHP_{t-1}	0.079 (1.37)	-0.103 (-0.665)	ΔNBP_{t-1}	0.212* (1.96)	0.291** (4.66)	0.148 (0.654)	0.081 (0.236)
		$\Delta TC1Y_{t-1}$	0.348** (5.57)	0.618** (8.39)	ΔSCP_{t-1}	0.209** (6.19)	-0.006 (-0.328)	-0.242** (-3.407)	-0.047 (-0.417)
					$\Delta TC3Y_{t-1}$	0.318** (10.00)	0.109** (5.882)	0.373** (5.571)	0.558** (2.682)
$\overline{R}^2$	0.310	$\overline{R}^2$	0.579	0.288	$\overline{R}^2$	0.646	0.317	0.112	0.231
AIC	-2.886	AIC	-3.377	-1.397	AIC	-3.545	-4.643	-2.058	-1.824
SC	-2.857	SC	-3.33	-1.352	SC	-3.486	-4.584	-1.999	-1.765
$Q(20)$	16.49 [0.686]	$Q(20)$	25.88 [0.17]	22.12 [0.33]	$Q(20)$	34.10 [0.03]	10.12 [0.96]	16.78 [0.67]	36.53 [0.02]
$Q^2(20)$	91.15 [0.00]	$Q^2(20)$	42.51 [0.00]	16.06 [0.71]	$Q^2(20)$	30.55 [0.06]	13.73 [0.84]	7.47 [0.99]	67.28 [0.00]

Notes: All the series are measured in logarithmic first differences. ΔSHP_t , ΔNBP_t , ΔSCP_t , $\Delta TC1Y_t$ and $\Delta TC3Y_t$ mean logarithmic first differences of second-hand prices, new-building prices, scrap prices, one-year and three-year timecharter prices for Panamax; see other notes to Table 6.9.

Table 6.11: Estimates of forecasting models for Handymax vessels during the period Jan 1990 to Jun 2009

	ARMA		VECM			VAR			
	ΔSHH_t		ΔSHH_t	$\Delta TC1Y_t$		ΔSHH_t	ΔNBH_t	ΔSCH_t	$\Delta TC3Y_t$
ΔSHH_{t-1}	0.545** (2.76)	Z_{t-1}	-0.02 (-1.61)	0.037 (1.49)	ΔSHH_{t-1}	0.022 (0.315)	0.025** (3.88)	-0.097 (-0.60)	-0.231** (-2.04)
		ΔSHH_{t-1}	-0.028 (-0.35)	-0.164 (1.02)	ΔNBH_{t-1}	-0.079 (-0.656)	0.246 (0.63)	0.075 (0.273)	-0.096 (-0.497)
		$\Delta TC1Y_{t-1}$	0.404** (8.73)	0.611** (6.65)	ΔSCH_{t-1}	0.072** (2.03)	0.002 (0.08)	-0.174** (-2.155)	-0.013 (-0.227)
					$\Delta TC3Y_{t-1}$	0.567** (9.18)	0.122** (3.62)	0.232** (1.645)	0.657** (6.685)
$\overline{R}^2$	0.294	$\overline{R}^2$	0.469	0.262	$\overline{R}^2$	0.570	0.280	0.009	0.258
AIC	-3.087	AIC	-3.364	-1.988	AIC	-3.569	-4.786	-1.922	-2.640
SC	-3.073	SC	-3.32	-1.943	SC	-3.510	-4.727	-1.863	-2.581
$Q(20)$	20.86 [0.405]	$Q(20)$	17.75 [0.64]	27.10 [0.13]	$Q(20)$	16.18 [0.70]	21.51 [0.37]	12.77 [0.88]	18.28 [0.28]
$Q^2(20)$	74.96 [0.00]	$Q^2(20)$	12.99 [0.91]	3.59 [0.99]	$Q^2(20)$	6.58 [0.99]	28.09 [0.11]	3.34 [0.99]	2.57 [1.00]

Notes: All the series are measured in logarithmic first differences. ΔSHH_t , ΔNBH_t , ΔSCH_t , $\Delta TC1Y_t$ and $\Delta TC3Y_t$ mean logarithmic first differences of second-hand prices, new-building prices, scrap prices, one-year and three-year timecharter prices for Handymax; See other notes to Table 6.9.

Table 6.12: The forecast performance of various models in the three markets

Panel A: Out-of-sample forecasts during the forecast period 2009.07-2010.12 for Capesize vessels												
	One-step ahead				*Two-step ahead*				*Three-step ahead*			
Model	N	RMSE	MAE	Theil's	N	RMSE	MAE	Theil's	N	RMSE	MAE	Theil's
RM	18	0.0320	0.0229	0.0031	17	0.0522	0.0438	0.0065	16	0.0691	0.0637	0.0086
ARMA	18	0.0299	0.0201	0.0037	17	0.0396	0.0322	0.0049	16	0.0484	0.0421	0.0060
ARMA-X	18	0.0356	0.0284	0.0044								
VECM	18	0.0378	0.0308	0.0047	17	0.0617	0.0523	0.0076	16	0.0962	0.0839	0.0119
VECM-X	18	0.0389	0.0319	0.0048								
VAR	18	0.0284	0.0210	0.0035	17	0.0457	0.0377	0.0057	16	0.0653	0.0560	0.0081
VAR-X	18	0.0333	0.0272	0.0041								
Panel B: Out-of-sample forecasts during the forecast period 2009.07-2010.12 for Panamax vessels												
	One-step ahead				*Two-step ahead*				*Three-step ahead*			
Model	N	RMSE	MAE	Theil's	N	RMSE	MAE	Theil's	N	RMSE	MAE	Theil's
RM	18	0.0301	0.0261	0.0042	17	0.0499	0.0446	0.0069	16	0.0649	0.0555	0.0090
ARMA	18	0.0277	0.0224	0.0038	17	0.0356	0.0327	0.0049	16	0.0426	0.0370	0.0059
VECM	18	0.0457	0.0325	0.0064	17	0.0804	0.0591	0.0112	16	0.1064	0.0854	0.0147
VAR	18	0.0251	0.0210	0.0035	17	0.0484	0.0394	0.0067	16	0.0565	0.0459	0.0078
Panel C: Out-of-sample forecasts during the forecast period 2009.07-2010.12 for Handymax vessels												
	One-step ahead				*Two-step ahead*				*Three-step ahead*			
Model	N	RMSE	MAE	Theil's	N	RMSE	MAE	Theil's	N	RMSE	MAE	Theil's
RM	18	0.0262	0.0212	0.0039	17	0.0406	0.0368	0.0060	16	0.0500	0.0444	0.0074
ARMA	18	0.0267	0.0189	0.0039	17	0.0336	0.0279	0.0050	16	0.0376	0.0318	0.0055
VECM	18	0.0262	0.0188	0.0039	17	0.0364	0.0300	0.0054	16	0.0530	0.0424	0.0078
VAR	18	0.0234	0.0159	0.0034	17	0.0321	0.0258	0.0047	16	0.0467	0.0377	0.0069

Notes: RMSE is the conventional root mean square error metric; MAE denotes mean absolute error and Theil's is the Theil's inequality coefficient.

Firstly, it can be seen that the incorporation of the US dollar index into various forecasting models of Capesize vessels seems not to be helpful in improving the forecasting performance. The ARMA-X performs worse than the ARMA model, the VECM-X model does not perform better than the VECM and the VAR-X model does not significantly outperform the VAR model.

Secondly, the VAR model outperforms the remaining time-series models for the forecasting horizon of one step ahead for all types of vessels, implying that the new-building, the scrap prices and three-year time-charter rates do provide the additional information in the prediction of second-hand ship prices in the short term.

Thirdly, the ARMA model gives the best estimates for two months and three months ahead in most cases, although this is reversed for the forecasts of two-steps ahead for Handymax vessels. It indicates that the ARMA model may improve the accuracy in the long-term prediction.

Finally, models with the equilibrium correction features (VECM and VECM-X) do not perform well as indicated by estimates of all assessing indicators across all forecasting horizons in three markets. The poor performance can be attributed to the use of the long-run relationship between second-hand ship prices and one-year timecharter rates. The equilibrium correction term forces variables to their average historical relationship, so long-term forecasts in particular may not be accurate if the underlying relationship has shifted.

6.5. Conclusions

This chapter examines the time-varying volatility of second-hand ship prices, dynamic relationships between ship prices and time charter rates, dynamic relations between ship prices including the new-building, the second-hand and scrap prices. Based on these studies, we develop several time-series models to forecast second-hand prices and the forecasting performance of each model is evaluated.

Variances of second-hand ship prices are found to be conditional and time varying for three types of dry bulk vessels during the sample period. Although ship prices apparently fluctuate more after 2003, compared to the years before 2003, the dummy of investigating the existence of volatility changing over market conditions is not found to be statistically significant. Second-hand prices of each ship size can move consistently in the long run, however, they fluctuate in their own way in the short run in each market. The Panamax segment seems to be affected greatest by old news, while new news seems to influence the Handymax sector most.

Our findings indicate that for the second-hand market, there exist cointegration relationships for the pair between spot rates and second hand ship prices, and also for the pair between one-year time charter rates and second hand ship prices. Three year time charter rates and second hand ship prices are not cointegrated statistically. Results show that second hand ship prices are determined primarily by charter rates, while prices in the freight market are influenced more by factors in its own market. Apart from charter rates, ship-owners’ expectations on the future market and cash flow can all have the substantial impact on second-hand ship prices. Therefore, diverse views on the future movement and different cash flow problems may result in the heterogeneous behavior of buying and selling second-hand ships, sometimes creating deviation of second-hand prices from charter rates.

The empirical results regarding the relationships among ship prices and charter rates reveal that time charter rates are found to be the main determinant of second-hand values. Changes in second-hand prices are significantly influenced by changes of scrap prices, and the effect of new-building prices on second hand prices is observed to be significant for Capesize and Panamax. Changes in second-hand prices do not have an impact on the movement of scrap prices. With regards to some economic indicators, the lagged exchange rate, represented by the US Dollar index seems to influence second hand prices significantly only for Capesize. The interest rate, represented by the LIBOR exhibits the mixed results for different ships.

The better understanding of the interrelationships between prices caused by the dynamic market mechanism for each ship size can help to make the reliable prediction of second-hand ship prices. Various time series models are constructed finally to forecast second hand ship prices during the period of July 2009 to Dec 2010. The exogenous variable in the time series models does not help to improve the forecasting performance. For the prediction of second-hand prices of one month ahead, the VAR model seems to be the most suitable one in three markets, while for the forecasts of two months and three months ahead, the ARMA model outperforms others and gives better results.

Chapter 7. Conclusions

This dissertation proposes strategies not only for modelling price behavior in the dry bulk market, but also for modelling relationships between economic and technical variables of dry bulk ships, by using modern time series approaches, Monte Carlo simulation and other economic techniques. The time series modelling techniques, described extensively in Appendix A, primarily consist of the Vector Error Correction model (VECM), the Vector Autoregressive model (VAR), the Autoregressive and Moving Average model (ARMA), the General Autoregressive Conditional Heteroskedasticity model (GARCH), and their extensions.

What are new and interesting here of the modelling strategies and their applications lie in several aspects:

- *Modelling variables of dry bulk ships:* the relationships between the economic performance and technical specifications of dry bulk vessels built over the period 1970 to 2008 are investigated in order to examine impacts of technical innovations during the past decades on the economic performance of dry bulk carriers. Furthermore, we construct a simulation-based optimization model to design a series of ships with different deadweight having the optimum main technical specifications and to obtain the optimum logistic plan for each vessel.
- *The extended time series models:* the ARIMA, VAR and VEC models are extended by including exogenous variables to become the ARIMAX, VARX and VECM-X models in order to investigate impacts of exogenous economic variables on charter rates and ship prices.
- *Dynamic behavior of prices and volatilities on major routes under diverse market conditions:* time series models are used to make the prediction of spot charter rates through an in-depth analysis of dynamic behavior between prices for Capesize, Panamax and Handymax vessels on specific major trading routes including the transatlantic, the fronthaul, the transpacific and the backhaul over the period 1990-2010 and over the period 2003-2010, respectively. Time series volatilities of charter rates, newbuilding prices and second-hand ship prices are examined over different periods as well.
- *Dynamic price behavior between different sub markets:* relationships in terms of returns and volatilities at different routes are examined by making use of daily figures between Capesize and Panamax markets, and between Panamax and Handymax markets. The lead-lag relationships of prices between the spot freight and the forward markets, and interrelationships of prices among the freight, the second-hand, the newbuilding and the scrap markets are investigated as well in this research.
- *The price behavior, the price discovery, and the forecasting performance of FFA prices are examined extensively*

The applications of different modelling strategies in the whole research yield a number of interesting and promising results as follows.

♦ *Findings regarding the economic performance and technical specifications of dry bulk vessels*

At first, some interesting conclusions come from the investigation on changes in main technical specifications of dry bulk vessels and relationships between these technical specifications and their economic performance in Chapter 2. It is interesting to find that the average design speeds for dry bulk vessels built over the period from 1970 to 2008 display a mixed picture with lower levels over the period from the early 1980s to the early 1990s, and with a slightly increasing tendency since the mid-1990s. To determine the design speed of a dry bulk vessel is, to a large extent, an economical choice, which is significantly influenced by economic indicators such as bunker costs and the market outlook.

Over the past decades from 1970 to 2008, the size of dry bulk carriers has been increased substantially and it is technically possible to build very large vessels within certain geographical limits. The expansion in deadweight is also triggered by economic factors. Generally, it is more economical to build a larger vessel than to increase the design speed if ship owners intend to improve the transport capacity of a ship. It is also interesting to find that the average lightweight of dry bulk vessels demonstrates a clearly decreasing trend. Roughly, a 20% reduction in lightship has been achieved through technical improvements in the past decades, including the improved hull structure, the reduced weight of the engine installed, and the use of high tensile steel. Decreasing the lightweight has a long-term effect on the earnings.

Additionally, it is important to find that technical innovations contribute to around a 40% decrease in the average fuel consumption per unit. By deepening the analysis, about 18–23% out of the total of 41% is caused by the technical improvement in hull form and propulsion system, and around 25% results from the technical improvement in the engine technology. The difference is reasonably acceptable due to differences in chosen sea-margins and the database. From an economic aspect, changes in the fuel consumption per unit have sizeable impacts on costs and earnings in the long run.

Elaborating such relationships has great implications to shipowners when building a new vessel, because bad ship designs are usually not uncommon, and it can also help shipowners to make suitable decisions to enhance the operating earnings when operating a vessel.

♦ *Findings regarding volatilities of prices in the freight market, the newbuilding market and the second-hand ship market*

Some findings are achieved regarding volatilities of prices in the freight market, the newbuilding ship market and the second-hand ship market, described in Chapters 4-6. In the freight market, volatilities of spot rates are found to be time-varying for three types of dry bulk vessels and heteroskedasticity also exists in returns of three-year time charter rates for Capesize and Panamax vessels. No time-varying conditional variation can be seen for one-year time-charter rates for three types of vessels and for three-year time charter rates of Handymax. With regards to volatility levels, the Capesize volatility lies above the volatilities of the other two sizes, and the Panamax volatility is in general at a level above Handymax. It is also revealed that the careful attention should be given to the diverse market situations, which may cause structural breaks. Compared to the period before 2003, the time-varying volatility is significantly larger since 2003 for spot and three-year time charter rates.

In the second-hand market, the variation of 5-year second-hand ship prices is found to be time varying and conditional for three ship sizes. The Handymax sector seems to be influenced most by the new shocks, while the Panamax seems to be affected most by the old news. While in the newbuilding ship market, no conditional variance is observed for the return series of new-building prices.

The comparison of these risk levels between different types of vessels may be regarded as a guide to holding different size vessels in ship-owners' dynamic varying portfolios, and the risk levels between different ship markets may provide useful information in making investment decisions.

♦ *Findings regarding the term structure analysis in the freight market*

With regards to the term structure analysis in the freight market, results in Chapter 4 indicate that the efficient market hypothesis is rejected for the pair between spot and one-year time charter rates, and for the pair between spot and three-year time charter rates during the sample period Jan 1990 to Dec 2010, consistent with findings in Kavussanos and Alizadeh (2002a).

There are some implications for the failure of the expectations theory. Firstly, the spot freight market is predictable and the past information can be used to make forecasts due to the failure of the efficient market hypothesis, Secondly, the excess profits may be made by operators who can get more information than others by switching between the spot and the period markets.

The rejection might be due to the existence of the risk premium, which may be time-varying. It is then revealed that the risk premium for Capesize and Panamax vessels is found to be time varying, while that for Handymax is constant. Furthermore, the time-varying risk premium can be seen to be negative during the strong freight market, while it is found to be insignificant during the weak freight market. Consequently, there are no robust conclusions which can be drawn regarding the signs and magnitudes of the risk premium in the freight market.

♦ *Findings regarding the lead-lag relationships in terms of returns and volatilities between different sub freight markets*

The lead-lag relationships in terms of returns and volatilities between different sub freight markets, explained in Chapter 4 reveal that the information transmission changes over time and varies differently dependent on each route between segments of Capesize and Panamax, and between segments of Panamax and Handymax. For Capesize and Panamax markets, only during the second sub-period 2003-2008, a bi-directional causal relationship in daily returns is observed on all routes. The results, in terms of volatilities, indicate that at the transatlantic route, there is a bi-directional relationship in volatility spillovers and the direction of the information flow seems to be stronger from the Capesize to the Panamax. At the fronthaul and transpacific route, volatilities in the Capesize market are transmitted to the Panamax, while the feedback effect is not significantly demonstrated. At the backhaul, there is no strong evidence of volatility spillovers in either market. During the first sub-period, there is a unidirectional relationship in returns and no volatility spillovers in any direction are found on all routes, and during the third sub-period, there is no cointegrating relationship between variables at four routes.

For Panamax and Handymax markets, Panamax prices and Handymax prices are not cointegrated during the first sub-period, while they are during the rest of the investigated periods at the fronthaul and the transpacific routes. At the backhaul route, Panamax and Supramax prices are only cointegrated during the second sub-period. Furthermore, no spillover effects in daily volatilities between these two markets can be found at the investigated routes.

♦ *Findings regarding the price discovery and the forecasting performance of FFA*

The price discovery and the forecasting performance of forward prices are investigated extensively and several main findings can be seen in Chapter 4. Forward prices seem to lead spot rates during different sub periods in all the investigated routes, including C4, C7, P2A and P3A. And there is a two-way feed back causal relationship between both price series, but the effect is stronger from the forward market to the spot market. This finding is expected, since it is clear that forward prices reveal information on the expectations of the market participants with regards to future spot rates from the way prices of freight forward contracts are formed. The FFA prices may thereby contain more information about future spot rates than the current and past spot prices alone.

The unbiasedness hypothesis in the freight forward agreements market of the dry bulk vessels is also investigated in Chapter 4, focusing on the routes C4, C7, P2A, P3A, TCC, TCP and TCH. The results indicate that freight forward prices one month prior to maturity are unbiased for all the routes with the exception of TCH. For the two months horizon, the unbiasedness hypothesis can be found at all routes. The unbiasedness hypothesis is supported as well for the three-month horizon. Whether the unbiasedness hypothesis holds for the dry bulk forward freight agreements thereby seems to depend on the route in question and time to maturity.

As a consequence, forward prices are thought to contain the useful information in predicting spot prices. The forecasting performance of daily forward prices and spot prices is investigated firstly. In general, as expected, the forecasting accuracy of all models generally declines as the forecasting horizon is increased from 1 day ahead to 20 days ahead. When comparing the models it is found that the VEC model with significant coefficients of error correction terms of opposite signs can give better results of forecasting daily spot and daily forward prices than other models, among which the VAR performs better than the ARMA. While for longer horizons, the ARMA model seems to outperform the VAR model.

Then the prediction of monthly time charter rates using monthly figures is investigated. The FFA prices one month prior to the maturity for the TCC, TCP and TCH, and the underlying monthly spot prices in each ship size market are employed in the forecasting models. Time-series models are generally found to perform worse than the forecasts indicated by the forward prices themselves for the one-month horizon for both Capesize and Panamax vessels, while for Handymax/Supramax vessels, no strong evidence shows that forward prices perform better than the VARX model.

These price discovery properties of the forward prices imply that market participants may use dry bulk freight forward prices to guide decisions in the physical market, and forward prices can thereby contribute to a more efficient allocation of economic resources.

- *Findings regarding relationships of prices among the freight market, the newbuilding ship market, the second-hand market and the scrap market*

The investigation on relationships of prices among the freight market, the newbuilding ship market, the second-hand ship market and the scrap market yields some interesting results.

For the new-building market, results in Chapter 5 reveal that time charter rates are the main determinant of new-building prices, because time charter rates may contain the future market information and they could be utilized by ship-owners in making their decisions of building new vessels. Newbuilding prices do not Granger cause charter rates, as expected and the new-building market seems to be little influenced by the second-hand and scrap markets. The shipbuilding market is a separate one, driven by more influences such as government policies, the financial policies and the shipbuilding capacity. Events in the shipbuilding market, therefore, do not always mirror those of the shipping market.

The monthly US dollar index, representing changes in the exchange rate of the US dollar against other currencies, and steel prices, representing the production costs, seem not to have significant impacts on prices of new vessels. While the LIBOR, representing the financial liquidity, exhibits the mixed results for different types of vessels.

For the second-hand market, cointegrated relationships exist for the pair between spot rates and second-hand ship prices, and also for the pair between one-year time charter rates and second-hand ship prices for three types of vessels. However, there is no cointegrated relationship between three-year time charter rates and second-hand prices across different ship sizes. Apart from charter rates, ship-owners' expectations on the future market and cash flow can all have substantial impacts on second-hand ship prices. Therefore, diverse views on the future movement and different cash flow problems may result in the heterogeneous behavior of buying and selling second-hand ships, sometimes creating deviation of second-hand prices from charter rates. What's more, second-hand prices are significantly influenced by changes in scrap prices, and the effect of new-building prices on second-hand prices is observed to be significant for Capesize and Panamax with the exception of Handymax. The US dollar index is found to be significant only for Capesize vessels, while the interest rate, represented by the LIBOR exhibits the mixed results for different ships.

For the demolition market, scrap prices may have a significant impact on the movement of spot rates instead of period ones, while changes in scrap prices are affected by one-year time charter rates instead of spot rates. Neither changes in new-building prices, nor changes in second-hand prices seem to have an impact on the movement of scrap prices.

♦ *Findings regarding the prediction of prices in the freight market, the newbuilding market and the second-hand market*

The prediction of spot rates on main trading routes for Capesize, Panamax and Handymax is described extensively in Chapter 4. There are two estimation periods, one is from Jan 1990 to June 2010, and the other is from Jan 2003 to June 2009. The period July 2009 to Dec 2010 is used for the out-of-sample forecasts. It is shown that the one-month change in the Baltic Indices during the current period contains information of the potential underlying demand change and the market sentiment, and has the substantial impact on the market movement next period. The US Dollar index and the exchange rate of US Dollar against EUR are also found to have the significant impact on spot prices. These variables are regarded as exogenous variables, they are therefore included into forecasting models.

The findings of forecasting models suggest that with the indicator of the one-month index change, a VAR model and a VAR-X model perform well on the out-of-sample forecasts against an ARIMA and an ARMAX. The VARX model estimated during the second period gives the best forecasting performance for the forecasts of one-period ahead on all routes for three types of vessels. For the two-period ahead and the three-period ahead forecasts, the VAR model of the second period outperforms better than that of the whole estimation period only in the Capesize market, while in the Panamax and the Handymax markets, there is no strong evidence showing that the VAR model of the second period can produce better forecasts.

The prediction of monthly newbuilding prices is discussed extensively in Chapter 5. The estimation period is from Jan 1990 to June 2009 for Panamax and Handymax and it is from Dec 1991 to June 2009 for Capesize. The period from July 2009 to Dec 2010 is used for the out-of-sample forecasts. Results indicate that the time series model yielding the best forecasting results is the ARMA model at various forecasting horizons for three types of vessels. The incorporation of second-hand ship prices and scrap prices does not provide additional information in the prediction of newbuilding ship prices, because parameters of second-hand ship prices and scrap prices are insignificant in the forecasting models. While it is also found that the inclusion of period charter rates in the VAR model and the long-run relationship between newbuilding ship prices and period charter rates in the VEC model seem not to be helpful in improving the forecasting performance of newbuilding ship prices during the forecasting period, although charter rates influence newbuilding prices significantly. The exogenous variables are found not to improve the forecasting performance of various models.

The prediction of monthly second-hand prices is described in detail in Chapter 6. The estimation period is from Jan 1990 to June 2009 for Panamax and Handymax and it is from Dec 1991 to June 2009 for Capesize. The forecast period is from July 2009 to Dec 2010. It can be seen that the incorporation of the US dollar index into the various forecasting models of Capesize vessels seems not to be helpful in improving the forecasting performance.

Generally, for the prediction of one month ahead, the VAR model seems to be the most suitable one in three markets, implying that the new-building, the scrap prices and three-year time-charter rates do provide the additional information in the prediction of second-hand ship prices in the short term. While for the forecasts of two months and three months ahead, the ARMA model outperforms others and gives better results, although this is reversed for the forecasts of two-step ahead for Handymax vessels. It indicates that the ARMA model may improve the accuracy in the long-term prediction.

The VECM and VECM-X do not perform well as indicated by estimates of all assessing indicators across all forecasting horizons in three markets. The poor performance can be attributed to the use of the long-run relationship between second-hand ship prices and three-year timecharter rates. The equilibrium correction term forces variables to their average historical relationship, so long-term forecasts in particular may not be accurate if the underlying relationship has shifted.

♦ *Findings regarding the optimization of ship designs*

In the shipbuilding market, top issues to buyers include not only when to order, but also what kind of vessels to order. In Chapter 5, the optimization model has been constructed and used to determine the dry bulk fleet with the optimum ship main dimensions and its power requirement at the conceptual design stage, together with the optimum logistic plan. The case study is executed for iron ore transportation during the voyage from Tubarao, Brazil to Beilun, China. The optimal ship size with main dimensions dependent on iron ore demand and the optimal logistic plan have been achieved through Monte-Cargo simulation. It is shown that the optimal ship size in each model is dependent on iron ore demand and the specific logistic plan. And constraints on the port draught determine main dimensions of a vessel. What's more, the inventory cost in the logistic plan is largely dependent on the order quantity and the reorder level.

The proposed methodology not only provides a tool to analyze the trade-off between total transport costs and inventory costs, but also it provides an insight into the interdependency of shore facilities, logistical aspects and ship design, and can offer the required flexibility in the decision-making for both dry bulk ship-owners and steel mills.

Limitations and further research

The work in this thesis inevitable has its limitations. An important limitation lies in the data. Time series modelling is an important part of the quantitative work in the whole research. Time series however, differ in the sample size, frequency and source. Charter rates are commonly measured on a monthly basis, some of which can be available on a daily basis. FFA prices can only be available on a daily basis from Baltic Exchange, not Clarkson Research Studies. Fleet variables, such as orderbook, deliveries and scrapping volumes, can be available monthly, and some trade flow variables can be measured in a monthly basis as well. However, FFA prices, fleet and trade variables are much less complete than the corresponding data sets of charter rates. Furthermore, the data of some variables sometimes may not represent the true levels of the dry bulk market, which can be arbitrarily revised or determined by chartering or ship brokers purposely. The more robust data can be the basis for substantial contributions to the maritime research. Another important limitation arises from the modelling strategy, which needs to be extended systematically in the further work.

Generally, the modelling approaches in this thesis are only applied in the chartering and ship markets of the dry bulk shipping. The modelling strategy could be applied to other bulk markets and container shipping market. There are several topics in this thesis which can be extended for further research.

♦ *Technical innovations beyond dry bulk ships and their impacts on the economic performance of vessels*

In Chapter 2, a framework is discussed to analyze relationships between the main technical variables and their impacts on the economic performance of a ship. However, impacts of technical changes beyond ships, such as technological innovations in terminals and logistical systems, are not studied in this thesis. For example, ships were loaded in the past with speeds around 3000 tons/h in comparison with nowadays 15 000 tons/h and more. The (un)loading rates are important for determining the voyage costs. Therefore, impacts of technical changes beyond ships, on costs and/or revenues of operating ships, as well as market decisions on building and/or sales and purchase of ships, are left for further study.

♦ *Making use of the Markov Regime Switching model to examine the dynamic variances of prices and risk premium in the freight market*

It is revealed in Chapter 4 that variances of charter rates and the risk premium in the freight market may change over time. It may be necessary to make use of the Markov Regime Switching Model to investigate the time-varying variation and dynamic risk premiums. Other extensions may be a strategy to deal with the cointegration with structural breaks. Since the period before and after 2003 are proved to be significantly different in this thesis, the modelling strategy here is to make use of the cointegration approach in separate sub periods to avoid structural breaks. The cointegration with structural breaks during the whole sample period could be tested in the future.

♦ *To investigate the investment timing of trading ships depending on trading rules and forecasts of time series models*

Chapter 5 and Chapter 6 present the investigation on the price behavior in the new-building and the second-hand markets, respectively. The investment timing of buying and selling ships, however, may be one of the most concerned topics of ship-owners or operators. The analysis of the investment timing can give rise to a number of potentially successful avenues for further research in the ship markets, by making use of the combined strategies of trading rules and time series forecasts.

♦ *The optimization approach of ship designs applicable to other types of vessels under different logistic situations*

The optimal ship designs for iron ore transportation from Tubarao, Brazil to Beilun, China are achieved through the simulation-based optimization approach in Chapter 5. This approach of acquiring the ship with the optimum ship design by minimizing the logistics cost is also applicable to various service requirements and to other types of vessels.

♦ *To do more in terms of forecast evaluation*

In Chapters 4-6, the forecasting models in different markets focus on predicting the mean values of prices in the freight market and ship markets for different types of vessels, while the variance and bias of forecast errors are little talked about. A further step to boost the contribution regarding forecasts is to do more in terms of forecast evaluation. For example, to test the significance of the performance differentials among the competing models through Diebold-Mariano type of tests for equal predictive ability and/or tests for superior predictive ability, such as the White’s (2000) Reality Check test and Hansen’s(2005) test for Superior Predictive Ability. By making such tests, we can know whether forecasts from different models produce significantly different results, or whether there is a particular forecasting model that significantly outperforms a set of alternative models.

Nederlandse samenvatting

Deze dissertatie stelt strategieën voor, niet alleen voor het modelleren van het prijsgedrag in de droge lading markt, maar ook voor het modelleren van relaties tussen economische en technische variabelen van droge lading schepen. Dit door de toepassing van moderne tijd serie benaderingen, Monte Carlo simulaties en andere technieken. De tijdreeks modelleringtechniek, beschreven in appendix A, bestaat voornamelijk uit het Vector Error Correction model, het Vector Autoregressie model, het algemene Autoregressieve Heteroskedastische model en hun uitbreidingen.

Nieuw in deze modelleringstrategieën en uitgewerkte toepassingen zijn:

- *Modelleringvariabelen van droge lading schepen*: de verbanden tussen de economische prestaties en de technische specificaties zijn onderzocht voor droge lading schepen over de periode 1970 tot 2008. Er is een op simulatie gebaseerd scheepsontwerp model gebouwd teneinde een serie schepen te ontwerpen met verschillend deadweight, met economisch gesproken optimale technische specificaties werkend in een optimale logistieke planning voor elk ontwerp.
- *De uitgebreide tijdreeksmodellen*: exogene variabelen zijn geïncorporeerd in de ARIMA, VAR en VEC modellen, zijnde ARIMAX, VARX en VECM-X om de invloed van exogene economische variabelen op de vrachtprijzen en scheepsprijzen te onderzoeken.
- *Dynamisch gedrag van prijzen en volatiliteit op de hoofdroutes onder diverse marktcondities:* tijdreeksmodellen zijn gebruikt om het dynamische gedrag tussen prijzen te analyseren, en om voorspellingen te maken van de spot vrachtprijzen op specifieke hoofd handelsroutes voor Capesize, Panamax en Handymax bulkcarriers, inclusief de trans-Atlantische, de “fronthaul” de trans-Pacifische routes en de “backhaul” gedurende de periode 1990-2010 en de periode 2003-2010. Ook zijn tijdreeksmodellen van de volatiliteit van de vrachtprijzen onderzocht over verschillende perioden.
- *Dynamisch prijs gedrag tussen verschillende sub-markten:* de verbanden tussen de Capesize en Panamax markten zijn onderzocht middels het gebruik van data op dagelijkse basis. Tevens prijsverbanden tussen de spot vracht en de termijn markten. Er is onderzoek gedaan naar mogelijke verbanden tussen de vracht, tweedehands, nieuwbouw en sloop markten.
- *Het prijsgedrag, de prijsvoorspelling, en kwaliteit van de voorspelling van FFA prijzen zijn diepgaand onderzocht*

De toepassing van verschillende modelstrategieën levert een aantal interessante en veelbelovende resultaten, te weten:

♦ *Bevindingen ten aanzien van de economische prestaties en technische specificaties van droge lading schepen.*

Dit onderzoek, beschreven in hoofdstuk 2, laat zien dat de gemiddelde ontwerpsnelheid van droge lading schepen gedurende de jaren enigszins varieert met lagere niveaus in de jaren 80 tot in de vroege negentiger jaren, en met een toenemende tendens sinds midden negentiger jaren. Het bepalen van de ontwerpsnelheid van een droge lading schip is tot op grote hoogte een economische keus welke zwaar beïnvloed wordt door de bunkerkosten en de markt vooruitzichten.

Over de laatste tientallen decennia zijn de afmetingen van bulkcarriers substantieel gegroeid, het is technisch al veel langer mogelijk om zeer grote schepen te bouwen. De vergroting van het deadweight is ook ingegeven door economische factoren. Over het algemeen is het economisch aantrekkelijker om grotere schepen te bouwen dan om de snelheid te verhogen als men de transportcapaciteit wil verhogen. Het is ook interessant om te zien dat het staalgewicht van de schepen duidelijk omlaag gegaan is. Ruwweg 20% reductie in staalgewicht is bereikt door technische verbeteringen in de afgelopen tientallen jaren. Hoofd oorzaken zijn verbeterde staal constructies, toepassing van het zogenaamde "High Tensile Steel" en een lager gewicht van de hoofdmotoren.. Afnemend staalgewicht heeft een positief lange termijn effect op de verdiensten.

Samenvattend kan gezegd worden dat de technische innovaties in de onderzochte periode bijgedragen hebben aan een verlaging van het brandstof verbruik van 40% voor zowel kleine als grote schepen. Meer in detail, ongeveer 18 tot 23% van de 41% is bereikt door een verbeterde rompvorm en een verbeterd voortstuwingssysteem en ongeveer 25 % daarvan is bereikt door verbeterde motortechnologie. Vanuit een economisch oogpunt kan gezegd worden dat de veranderingen in het brandstofverbruik per eenheid een substantiële invloed hebben gehad op de kosten en verdiensten op de lange termijn.

Het onderzoeken van dergelijke relaties kan grote gevolgen hebben voor scheepseigenaren wanneer zij een nieuw schip willen gaan bouwen. Het kan hen helpen om de juiste beslissingen te nemen om de operationele opbrengsten te verbeteren.

♦ *Bevindingen ten aanzien van de volatiliteiten van de prijzen in de vrachtmarkt, de nieuwbouwmarkt en de tweedehands markt.*

Enkele conclusies kunnen getrokken worden ten aanzien van de volatiliteit van de prijzen in de vrachtmarkt, de nieuwbouwmarkt en de tweedehandsmarkt. De details zijn te vinden in de hoofdstukken 4-6. De volatiliteit van de spotprijzen, bijvoorbeeld, variëren in de tijd voor 3 type bulkcarriers en heteroskedasticiteit bestaat ook in de opbrengsten van de drie jaar tijdcharterprijzen voor Capesize en Panamax schepen. Er zijn geen voorwaardelijke variaties in de tijd gevonden voor de 1 jaar tijdcharters voor alle drie types bulkcarriers en ook niet voor de drie jaar tijdcharter prijzen van het Handymax type.

Ten aanzien van de volatiliteit van de vrachtprijzen kan gezegd worden dat de volatiliteit bij de Capesize carriers groter is dan bij de andere typen, en de volatiliteit bij de Panamax carriers ligt in het algemeen boven het niveau van de Handymax carriers. De diverse markt situaties kunnen echter een grote invloed hebben. Vergeleken met de periode van voor 2003 zijn de voorwaardelijke variaties van de volatiliteit in de tijd opmerkelijk lager sinds 2003 voor de spot en de drie jaar tijdcharter prijzen.

De voorwaardelijke variaties in de tijd van de tweedehands prijzen van 5 jaar oude schepen is duidelijk aanwezig voor 3 scheepstypen.. De Handymax sector schijnt het meest direct beïnvloed te worden door nieuwe schokken in de markt terwijl de Panamax prijzen meer beïnvloed worden door wat ouder nieuws. De vrachtmarkt heeft echter geen grote invloed op de volatiliteit van deze prijzen.

In de nieuwbouwmarkt zijn geen grote conditionele variaties waargenomen in de nieuwbouwprijzen. Vergelijking van de risico niveaus tussen de verschillende typen schepen zou kunnen leiden tot het aanbrengen van enige variatie in de afmetingen van de schepen in de vloot van een scheepseigenaar. Ook kan de kennis over de verschillen in risico niveaus van de verschillende scheepsmarkten nuttig gebruikt worden bij het voorbereiden van investeringsbeslissingen.

♦ *Bevindingen ten aanzien van de termijn structuur analyse in de vrachtmarkt.*

Ten aanzien van de termijn structuur analyse in de vrachtmarkt is te zien in hoofdstuk 4 dat de efficiënte markt hypothese verworpen moet worden voor de vergelijking tussen spot en 1 jaar tijdcharter prijzen, maar ook voor de vergelijking tussen spot en 3 jaar tijdcharter prijzen gedurende de periode Jan 1990 tot December 2010. Dit komt overeen met de bevindingen van Kavussanos en Alizadeh (2002a)

Het falen van de "expectations theory" heeft enkele consequenties. Ten eerste dat de spot vrachtmarkt voorspelbaar is en de informatie uit het verleden bruikbaar is om marktvoorspellingen te doen, dit als gevolg van het weerleggen van de efficiënte markthypothese. Ten tweede kunnen er excessieve winsten gegenereerd worden door operators die meer informatie hebben dan anderen, door tijdig te wisselen tussen de spot- en de periodemarkten.

De verwerping zou een gevolg kunnen zijn van het bestaan van een risico premie, welke voorwaardelijk tijdsveranderlijk zou kunnen zijn. Er is een voorwaardelijke tijdsveranderlijke risico premie gevonden voor Capesize en Panamax schepen. Voor de Handymax schepen is deze constant. De voorwaardelijke tijdsveranderlijke risicopremie is negatief gedurende een sterke vrachtmarkt en onbetekenend gedurende een zwakke vrachtenmarkt. Robuuste conclusies ten aanzien van het voorkomen en de omvang van de risico premie in de vrachtmarkten kunnen helaas niet getrokken worden.

♦ *Bevindingen ten aanzien van de verbanden tussen de opbrengsten en volatiliteit tussen de diverse vracht markten op de hoofd routes.*

De verbanden inzake opbrengsten en volatiliteiten tussen de diverse sub-vrachtmarkten op de hoofdroutes is geanalyseerd in hoofdstuk 4 en laat zien dat de informatie transmissie in de tijd verandert en verschillend varieert afhankelijk van elke route tussen segmenten van de Capesize en Panamax markten tussen segmenten van de Panamax en Handymax markten. Voor de Capesize en Panamax markten is alleen gedurende de tweede sub-periode 2003-2008 een bi-directioneel oorzakelijk verband gevonden in dagelijkse opbrengsten op alle routes. De resultaten ten aanzien van de volatiliteit indiceren dat op de trans-Atlantische route het bi-directioneel verband bij het overvloeien van de volatiliteit, en de richting van de informatiestroom, sterker is van de Capesize naar de Panamax toe. In de "fronthaul" en op de trans-Pacifische route vloeit de volatiliteit van de Capesize naar de Panamax markt, terwijl het terugkoppelingseffect niet duidelijk aangetoond is. Op de "backhaul" routes is geen sterk bewijs van het overvloeien van volatiliteiten. Gedurende de eerste subperiode is er een unidirectioneel verband in opbrengsten en geen overvloeing van volatiliteit in welke richting of op welke route dan ook. Gedurende de derde sub periode is er in het geheel geen co-integratie gevonden tussen de variabelen op vier routes.

De Panamax prijzen en Handymax prijzen zijn niet gecointegreerd gedurende de eerste subperiode, terwijl dat wel het geval is in de andere onderzochte perioden bij de "fronthaul" en op de trans pacifische route. Op de "backhaul" route zijn alleen de Panamax en Supramax prijzen gecointegreerd gedurende de tweede subperiode. Verder is er geen overvloeiing van volatiliteiten tussen deze markten aangetroffen op alle onderzochte routes.

♦ *Bevindingen ten aanzien van de prijs voorspellingen en de voorspelling performance van de FFA.*

De prijsvoorspelling en de voorspellingsperformance van termijn prijzen zijn uitgebreid onderzocht in hoofdstuk 4. Termijn prijzen schijnen de spot rates te sturen gedurende de verschillende subperioden en op alle routes, inclusief C4, C7, P2A en P3A. Er is een oorzakelijk verband in de vorm van een terugkoppeling in twee richtingen tussen de beide prijs series, het effect is echter sterker van de termijn markt naar de spot markt. Dit was verwacht, de termijn markt weerspiegelt immers de verwachtingen. De FFA prijzen zouden derhalve meer informatie kunnen bevatten over de toekomstige spotprijzen dan de oude en huidige spotprijzen alleen.

De "unbiasedness hypothesis" in de termijn vrachtmarkt van droge lading schepen is ook onderzocht in hoofdstuk 4, met name op de routes C4, C7, P2A, P3A, TCC, TCP en TCH. De resultaten indiceren dat de 1 maands prijzen op de termijn markt “unbiased” zijn voor alle routes behalve voor de TCH route. Voor een horizon van 2 maanden is dit ook het geval, de termijn prijzen op alle routes zijn dan “unbiased”. Voor de 3 maands horizon is de “unbiasedness hypothesis” echter verworpen voor de routes C7 en P2A en aangenomen voor de routes C4 en PA. Of de hypothese aangenomen moet worden voor de droge lading termijn markt schijnt afhankelijk te zijn van de route en de horizon van het contract.

Concluderend, termijn prijzen worden geacht de informatie te bevatten om de spot prijzen te voorspellen. De voorspellingsperformance van de dagelijkse termijnprijzen en de spotprijzen is als eerste onderzocht. In lijn met de verwachting neemt de accuraatheid van de voorspelling af met het toenemen van de voorspellingshorizon van 1 naar 20 dagen. Op basis van modelvergelijking is geconstateerd dat het VECM model met behoorlijke coëfficiënten voor foutcorrectie termen met tegengestelde tekens betere resultaten geeft bij de voorspelling van de dagelijkse spot markt en termijn markt dan andere modellen. Van deze andere modellen functioneert de VAR beter dan de ARMA. Terwijl voor een grotere horizon het ARMA model het wint van het VAR model.

De voorspelling van de 1 maands timecharter rates zijn ook onderzocht op basis van maandcijfers. In de modellen zijn de FFA prijzen met een horizon van 1 maand op de TCC, TCP en TCH routes en de onderliggende maandelijkse spotprijzen per scheepsgrootte segment gebruikt. Tijdserie modellen bleken over het algemeen slechter te werken dan voorspellingsmethoden gebaseerd op de termijnmarkt prijzen voor een horizon van 1 maand. Overigens met als uitzondering het VARX model. Het VARX model maakt de beste voorspellingen voor de spotprijzen van de Capesize en Panamax schepen. Voor de Handymax/Supramax schepen is er echter geen sterk bewijs dat de termijn prijzen een betere basis zijn voor de voorspelling dan het VARX model.

Deze prijsvoorspellingseigenschappen van de termijnprijzen impliceren wellicht dat de marktparticipanten zich laten leiden door de termijnprijzen in de werkelijke markt, de termijnprijzen kunnen derhalve bijdragen in het efficiënt alloceren van economische middelen.

♦ *Bevindingen ten aanzien van de verbanden tussen de vrachtenmarkt, nieuwbouwmarkt, tweede hands markt en sloopmarkt.*

Het onderzoek in hoofdstuk 5 naar de verbanden tussen deze markten heeft een aantal interessante resultaten opgeleverd. Bij de nieuwbouwmarkt is een duidelijke sturing gevonden van de nieuwbouwprijzen door de timecharter prijzen. Dit is waarschijnlijk omdat de timecharterprijzen informatie over de toekomstige markt bevatten en derhalve gebruikt kunnen worden bij besluitvormingsprocessen ten aanzien van nieuwbouw. Nieuwbouwprijzen bepalen niet de charter rate, zoals verwacht, en de nieuwbouwmarkt schijnt slechts in geringe mate beïnvloed te worden door de tweedehands markt en de sloopmarkt. De scheepsbouwmarkt is een aparte markt, gedreven door meer invloeden zoals bijvoorbeeld het overheidsbeleid, algemeen financieel beleid of de scheepsbouwcapaciteit. Gebeurtenissen in de scheepsbouwmarkt reflecteren daardoor niet altijd de scheepvaartmarkt.

De maandelijkse US dollar index, wisselkoersveranderingen weergevend ten opzichte van andere munteenheden, en de staalprijzen, een indicatie voor de productiekosten, schijnen beide geen belangrijke invloed te hebben op de scheepsnieuwbouw prijzen. De LIBOR, indicatief voor de financiële liquiditeit, geeft gemengde resultaten voor de verschillende scheepsgrootten.

Op de tweedehands markt is er een gecointegreerd verband gevonden tussen de spot charter rates en de tweedehands waarde van schepen en ook tussen 1 jaar timecharter rates en tweedehands scheepsprijzen voor 3 scheepstypes. Een gecointegreerd verband tussen de 3 jaars timecharter rates en de tweedehands waarde van schepen is voor geen enkele scheepsgrootte gevonden. Ook de verwachtingen van de scheepseigenaren ten aanzien van de toekomstige markt en de cashflow situatie in het algemeen kunnen een substantiële invloed hebben op de tweedehands waarde van schepen. Bepaalde markt verwachtingen en meer generieke cashflow problematieken kunnen derhalve leiden tot een meer heterogeen koop en verkoopgedrag waardoor het meer generieke verband met de charter rates tijdelijk afwezig is. Wat wel duidelijk is, is de invloed van de slooprijzen op de tweedehandsmarkt. Bij de Capesize en Panamax schepen met uitzondering van de Handymax is er ook een significante invloed geconstateerd van de nieuwbouwprijzen op de tweedehandsprijzen. De US dollar index heeft een behoorlijke invloed op de Capesize schepen terwijl de LIBOR als scheepsprijs beïnvloedende factor voor de diverse scheepstypes gemengde resultaten oplevert.

In de spot markt hebben de slooprijzen een behoorlijke invloed op de spot rates, dit terwijl de slooprijzen zelf wel beïnvloed worden door de 1 jaar timecharter prijzen. De sloop prijzen worden echter niet beïnvloed door veranderingen in de nieuwbouwprijzen en tweedehands prijzen.

♦ *Bevindingen ten aanzien van de voorspelling van de vrachtenmarkt, nieuwbouwmarkt en de tweedehands markt.*

De voorspelling van de spot rates op de hoofd handelsroutes voor de Capesize, Panamax en Handymax is uitgebreid beschreven in hoofdstuk 4. De database waarop de voorspellingen zijn gebaseerd is gesplitst in 2 perioden, januari 1990 tot juni 2010 en januari 2003 tot juni 2009. De periode juli 2009 tot december 2010 is gebruikt voor het doen van voorspellingen in een gebied dat buiten de database ligt welke gebruikt is voor het maken van de modellen, verderop wordt deze periode de testperiode genoemd. Het is gebleken dat de 1 maands index veranderingen gedurende de lopende periode informatie bevat betreffende de potentiële vraag veranderingen en het marktsentiment, derhalve bepalend voor de marktbewegingen in de volgende periode.

De US dollar index en de wisselkoersen van de US dollar tegen de euro hebben ook een grote invloed op de spot prijzen. Deze varabelen worden beschouwd als exogene varabelen en zijn daarom in het model opgenomen.

De voorspellingsmodellen laten zien dat bij het gebruik van de 1 maands index veranderingsindicator in de modellen, het VAR model en het VARX model goed presteren in de testperiode, beter dan het ARIMA en het ARMAX model. Het VARX model gebaseerd op de tweede data periode geeft de beste voorspellingen, 1 periode vooruit, op alle routes voor 3 scheepstypes. Voor de voorspellingen van 2 en ook 3 periodes vooruit is het VAR model, gebaseerd op de tweede data periode, beter presterend ten aanzien van de Capesize markt dan het VAR model gebaseerd op de eerste data periode. Dit terwijl in de Handymax en Panamax markt niet is aangetoond dat het VAR model gebaseerd op de tweede data periode betere voorspellingen genereert.

De voorspelling van de maandelijkse nieuwbouwprijzen is uitgebreid besproken in hoofdstuk 5. De database voor de Panamax en Handymax schepen is van januari 1990 tot juni 2009, voor de Capesize van december 1991 tot juni 2009. De testperiode is van juli 2009 tot december 2010. De resultaten geven aan dat het beste tijdserie model het ARMA model is, dit bij diverse voorspelling horizons en voor drie typen schepen. Het meenemen van tweedehandsscheepsprijzen en slooprijzen heeft geen toegevoegde waarde bij de voorspelling van de nieuwbouwprijzen, dit omdat de daaruit voortvloeiende parameters in de modellen slechts zeer geringe invloeden hebben. Ook werd geconcludeerd dat het inbouwen van timecharter rates in het VAR model en het lange termijn verband tussen de nieuwbouwprijzen en de timecharter rates in het VECM model niet behulpzaam zijn bij het verbeteren van de voorspelling van de nieuwbouwprijzen gedurende de voorspellingsperiode, dit ondanks dat de charter rates de nieuwbouwprijzen behoorlijk beïnvloeden. Het toepassen van exogene variabelen had geen model verbeteringen tot gevolg.

De voorspelling van de maandelijkse tweedehandsprijzen is uitgebreid beschreven in hoofdstuk 6. Het model is gebaseerd op een database van de periode januari 1990 tot juni 2009 voor Panamax en Handymax en van december 1991 tot juni 2009 voor Capesize carriers. De testperiode is van juli 2009 tot december 2010. Het is duidelijk gebleken dat het inbouwen van de US dollar index in de diverse voorspellingsmodellen voor de Capesize tweedehands prijzen geen verbetering oplevert.

Over het algemeen kan gezegd worden dat het VAR model voor de voorspellingen van 1 maand vooruit het meest geschikt lijkt voor alle drie de markten. Dit impliceert dat de nieuwbouwprijzen, de sloopprijzen en de 3 jaars timecharter rates de beste informatie bevatten om de tweedehands prijzen op de korte termijn te voorspellen. Terwijl voor de voorspellingen over 2 maanden en 3 maanden vooruit het ARMA model betere resultaten geeft. Dit is niet het geval voor de 2 maand vooruit voorspelling van de Handymax tweedehandsprijzen. Dit is een indicatie dat het ARMA model mogelijk de nauwkeurigheid van de voorspellingen op de lange termijn verbetert.

The VECM en het VECM-X model tonen geen overtuigende resultaten op alle voorspelling horizons. Deze slechte performance kan toegeschreven worden aan het gebruik van het lange termijn verband tussen de tweede hands scheepsprijzen en de 3 jaars timecharter rates, dit omdat de evenwicht correctie term de variabelen forceert in de richting van de gemiddelde historische relatie, dus lange termijn voorspellingen in het bijzonder zijn wellicht niet zo nauwkeurig als de onderliggende relaties inmiddels verschoven zijn.

♦ *Bevindingen ten aanzien van het optimaliseren van het scheepsontwerp.*

In de scheepsbouwmarkt is het een belangrijk issue wanneer er besteld moet worden, maar ook wat voor soort schip. In hoofdstuk 6 is een scheepsontwerp en vloot optimalisatiemodel beschreven. Deze is gebruikt om zowel het optimale scheepsontwerp in termen van scheepsverhoudingen en ideale vermogen/snelheden te produceren als wel daarmee een optimale scheepsgrootte te bepalen in een virtueel logistiek systeem. Het doel is een systeem te genereren met de laagste kosten per ton mijl. Het model is gebruikt om een casestudie uit te voeren. Deze is uitgevoerd voor het transport van ijzererts van Tubarao in Brazilië naar Beilun in China. De ideale scheepsgrootte is bepaald met een Monte Carlo simulatie van het totale logistieke plaatje inclusief de hoogovenproductie en opslagsystemen. Het is gebleken dat de ideale scheepsgrootte afhankelijk is van de vraag naar ijzererts en het specifieke logistieke plaatje.

Tevens is gebleken dat diepgangsbeperkingen in de havens de performance van het scheepsontwerp negatief beïnvloeden. Ook is geconcludeerd dat de voorraadkosten in het logistieke plan sterk afhankelijk zijn van de ordergrootte, en dus de scheepsafmeting, maar ook van het minimum voorraad niveau waarop nieuwe orders geplaatst worden.

De voorgestelde methodologie verschaft niet alleen een gereedschap om de "trade off" te analyseren tussen totale transportkosten en voorraadkosten maar verschaft ook inzichten in de afhankelijkheden tussen faciliteiten op het land, logistieke aspecten en scheepsontwerp, het kan de vereiste flexibiliteit opleveren in het besluitvormingsproces van beide de droge lading scheepseigenaren en de staal producerende bedrijven.

Bibliography

Aalbers, A. (2000). Evaluation of ship design alternatives, *In proceedings of the 34th Wegemt School*, June, Delft, the Netherlands, 1-16.

Adland, R and Cullinane, K. (2005) A time-varying risk premium in the term structure of bulk shipping freight rates, *Journal of Transport Economics and Policy,* 39(2): 191-208.

Adland, R and Strandenes, S.P. (2007). A discrete-time stochastic partial equilibrium model of the spot freight market. *Journal of Transport Economics and Policy*, 41(2): 189-218.

Akaike, H. (1973) Information theory and an extension of the maximum likelihood principle. (In Ed.) Petrov, B. N. and Csaki, F., *Proceedings of the 2nd International Symposium on Information Theory*, Akademia Kiado, Budapest, 267-281.

Alizadeh, A. (2001) An econometric analysis of the dry bulk shipping industry; seasonality, efficiency and risk premia, unpublished PhD Thesis, City University Business School, London, UK.

Alizadeh, A. and Nomikos, N. (2003) The price-volume relationship in the sale and purchase market for dry bulk vessels. *Maritime Policy & Management,* 30: 321–337.

Alizadeh, A. and Nomikos, N. (2010) An overview of the dry bulk shipping industry, In: *The Handbook of Maritime Economics and Business*, edited by C.Th. Grammenos. London: Lloyd's Lis, pp.319-354.

Assumma, V. and Vitetta, A. (2006). Micro simulation models in a RO-RO high speed services intermodal container terminal: Ordinary and perturbed conditions. *European Transport Conference*, Strasbourg, France, September, 2006.

The Baltic Exchange, www.balticexchange.com 2010.

Baillie, R.T. and Bollerslev,T. (1995). On the interdependence of international asset markets. In: Aggarwal, R., Schrim,D. (Eds), *Global Portfolio Diversification: Risk Management, Market Microstructure and Implementation Issues.* Academic Press, New York, 19-29.

Batchelor, R., Alizadeh, A. and Visvikis, I. (2007). Forecasting spot and forward prices in the international freight market. *International Journal of Forecasting,* 23: 101-114.

Beenstock, M. (1985). A Theory of Ship Prices. *Maritime Policy and Management,* 12: 215-225.

Beenstock, M. and Vergottis, A. (1993) *Econometric Modelling of World Shipping,* 1st edition, Chapman and Hall, London, UK.

Berndt, E. K., Hall, B. H., Hall, R. E. and Hausman, J. A. (1974). Estimation and inference in nonlinear structural models, *Annals of Economic and Social Measurement,* 3/4: 653–665.

Bierens, H.J. (1987). ARMAX model specification testing, with an application to unemployment to the Netherlands, *Journal of Econometrics,* 35 (1): 161-190.

Black, F. (1976). Studies in stock price volatility changes, *Proceedings of the 1976 Meeting of the Business and Economics Statistics Section*, American Statistical Association, pp. 177-181.

Bollerslev, T. (1986). Generalised Autoregressive Conditional Heteroskedasticity. *Journal of Econometrics*, 31:307-327.

Bollerslev, T. (1987) A conditional heteroskedastic time series model for speculative prices and rates of return. *Review of Economics and Statistics*, 69: 542-547.

Bollerslev, T and Wooldridge, J.M. (1992) Quasi-maximum likelihood estimation of dynamic models with time-varying covariance. *Econometric Reviews*, 11: 143-172.

Bollerslev, T., Engle, R. F and Nelson, D. B. (1994). ARCH models, in R. Engle & D. McFadden (eds.), *Handbook of Econometrics*, Vol. 4, Elsevier Science Publishers, Amsterdam.

Bollerslev, T., Chou, R.Y. and Kroner, K. F. (1992). ARCH modelling in finance: A review of the theory and empirical evidence, *Journal of Econometrics*. 52: 5-59.

Box, G. E. P. and Jenkins, G. (1970). *Time series analysis, forecasting and control.* San Francisco: Holden-Day.

Brockwell, P. J. and Davis, R. A. (1987). *Time Series: Theory and Methods*, New York: Springer-Verlag.

Buxton, I.L. (1987). *Engineering Economics and Ship Design.* Wallsend: British Maritime Technology Limited.

Campbell, J. Y. and Shiller, R. J.(1987). Cointegration and tests of present value models, *Journal of Political Economy*, University of Chicago Press, 95(5): 1062-88, October.

Charnes, J. (2007). *Financial Modelling with Crystal Ball and Excel.* Hoboken: John Wiley & Sons, Inc,.

Chang, Y. and Chang H. (1996). Predictability of the dry-bulk shipping market by BIFFEX. *Maritime Policy and Management*, 23: 103-114.

Chen, Y.S. and Wang, S. T. (2004). The empirical evidence of the leverage effect on volatility in international bulk shipping market. *Maritime Economics and Logistics*, 31: 109-124.

Clarkson Research Studies (2008) *Dry Bulk Trade Outlook*. Clarksons Publications, London, December.

Clarkson Research Studies (2004). *The Tramp Shipping Market*, Clarkson Research Studies, April 2004.

Clarksons Shipping Intelligence Network (2010) http://www.clarksons.net/

Hendry, D.F. and Ericsson, N.R. (2001). *Understanding Economic Forecasts*, Cambridge, Mass.: MIT Press.

Cufley, C.B.F (1972). *Ocean freights and chartering*, London: Staples Press

Cullinane, K. (1992). A short-term adaptive forecasting model for BIFFEX speculation: A Box-Jenkins approach. *Maritime Policy and Management*, 19: 91-114.

Cullinane, K and Khanna, M (1999). Economies of scale in large container ships, *Journal of Transport Economics and Policy*, 33 (2): 185-208.

Cullinane, K. and Khanna, M.(2000) Economies of scale in large containerships: Optimal size and geographical implications, *Journal of Transport Geography*, 8: 181-195.

Cullinane, K., Mason, K. J. and Cape, M. B. (1999). A comparison of models for forecasting the Baltic freight index: Box–Jenkins revisited. *International Journal of Maritime Economics*, 1(2): 15-39.

Dickey, D. and Fuller, W. (1981) Likelihood ratio statistics for autoregressive time series with a unit root. *Econometrica*, 49: 1057-1072.

Dikos, G.(2004) New building prices: demand inelastic or perfectly competitive. *Maritime Economics and Logistic*,6(4):312-321.

Diebold, F.X. and Mariano, R. S. (1995). Comparing Predictive Accuracy. *Journal of Business and Economic Statistics*, 13(3), 253–263.

Doornik, J. A., Hendry, D. F. and Nielsen, B. (1998). Inference in cointegrating models, UK M1 revisited, *Journal of Economic Surveys*, 12: 533-572.

Drewry Dry Bulk Forecaster (2007). Drewry Consultancy, http://www.drewry.co.uk/publications

Drewry Dry Bulk Forecaster (2008). http://www.drewry.co.uk/publications.

Engle, R. F. (1982) Autoregressive conditional heteroskedasticity with estimates of the variance of United Kingdom inflation, *Econometrica* 50(4): 987-1007.

Engle, R. F. and Granger, C. W. J. (1987). Co-integration and error correction: Representation, estimation, and testing. *Econometrica*, 55: 251-276.

Engle, R. F., Hendry, D. F. and Richard, J.F. (1983). Exogeneity, *Econometrica* 51: 277-304.

Engle, R.F. and Yoo, B. S. (1987). Forecasting and Testing in Cointegrating Systems, *Journal of Econometrics*, 35:143-59.

Engle, R.F. and Rodrigues, A. (1989). Tests of international CAPM with time-varying covariances. *Journal of Applied Econometrics*, 4:119-138.

Eriksen, I.E.(1982). The demand for bulk ship services. In: *Studies in Shipping Economics*, ed. E.Hope. Oslo: Bedriftsøkonomens Forlag A-S.

Evans, J.R. (2007). *Statistics, Data Analysis and Decision Modelling.* New Jersey: Pearson/Prentice Hall.

Fama, E.F. (1965). The behavior of stock-market prices. *Journal of Business*, 38(1): 34-105

Fama, E.F. (1991). Efficient capital markets II. *Journal of Finance*, 46, 1575-1617.

Fayle, E.C.(1933) *A Short History of the World's Shipping Industry*, London: George Allen&Unwin.

Fiorentini, G., Calzolari, G. and Panattoni, L. (1996). Analytic derivatives and the computation of GARCH estimates, *Journal of Applied Econometrics* 11: 399-417.

Frouws, J. W.(2010): Conceptual design of economical vessels, In: *Applied Transport Economics*, edited by E.Van De Voorde and T.Vanelslander, Antwerp: De Boeck, pp. 176-199.

Fuller, W. A. (1976). *Introduction to Statistical Time Series*, John Wiley & Sons, New York.

Franses, P.H., (1991). Primary demand for beer in the Netherlands: An application of ARMAX model specification. *Journal of Marketing Research*, 28: 240-245.

Garrod, P. *and* Miklirs, W. *(*1985). The optimal ship size*: a comment. Journal of Transport Economics and Policy* 19(1): 83.

Glasserman, P. (2004). *Monte Carlo Methods in Financial Engineering.* New York: Springer Science & Business Media, Inc.

Glen, D.R. (1997). The market for second-hand ships: Further results on efficiency using cointegration analysis. *Maritime Policy and Management*, 24: 245-260.

Glen, D.R. (2006). The modelling of dry bulk and tanker markets: a survey. *Maritime Policy and Management* 33(5): 431-445.

Glosten, Lawrence R., Jagannatan, Ravi, and Runkle, David E. (1993). On the relation between the expected value and the volatility of the nominal excess returns on Stocks, *Journal of Finance,* 48(5), 1779-1801.

Granger, C.W.J. and Newbold, P. (1974). Spurious Regressions in Econometrics. *Journal of Econometrics*, 2: 111-120.

Granger, C.W. J. (1981). Some properties of time series data and their use in econometric model specification, *Journal of Econometrics,* 16: 121-130.

Granger, C. W. J. (1988). Some recent developments in a concept of causality. *Journal of Econometrics* 39(1-2): 199-211.

Greene, W.H. (1990). *Econometric analysis*, Macmillan Publishing Company, New York.

Grammenos, C.Th., Editor (2010). *The Handbook of Maritime Economics and Business,* London: London Press, 2nd edition, 2010.

Grammenos C. Th. (2002). Credit risk analysis and policy in bank shipping finance, In: Grammenos, C. Th. (ed.), *The Handbook of Maritime Economics and Business,*2nd edition, London: London Press (LLP), pp 777-804.

Hawdon, D. (1978). Tanker freight rates in the short and long run. *Journal of Applied Economics*, 10.

Haigh, M. (2000). Cointegration, unbiased expectations and forecasting in the BIFFEX freight futures market. *Journal of Futures Markets*, 20: 545-571

Hale, C. and Vanangs, A. (1992). The market for second hand ships: some results on efficiency using cointegration. *Maritime Policy and Management*, 19(19), 31-40.

Hampton, M.J.(1990). *Long and Short Shipping Cycles.* Cambridge: Cambridge Academy of Transport, 2nd version 1990, p2, p40-49.

Hamilton, J.D. (1994). *Time Series Analysis*, Princeton University Press, Princeton, New Jersey.

Hansen, P. R. (2005). A Test for Superior Predictive Ability. *Journal of Business and Economic Statistics*, 23(4), 365–380.

Harvey, A.C.(1990). *The econometric analysis of time series*, MIT Press, Cambridge, MA.

Harvey, D. I., Leybourne, S. J. and Newbold, P. (1997). Testing the equality of prediction mean squared errors. *International Journal of Forecasting*, 13, 281–291.

Holtrop, J. and Mennen, G.G.J. (1979). Het voorspellen van het voortstuwingsvermogen in het voorontwerpstadium op grond van statistische gegevens. *Schip en Werf*, 12: 100-103.

Hughes, C. (1996). *Ship Performance*, London: LLP.

Hubrich, K., Lütkepohl, H. and Saikkonen, P. (2001). A review of systems cointegration tests, *Econometric Reviews* 20: 247-318.

International Maritime Organization (1999). *New IMO bulk carrier regulations enter into force on 1 July 1999*. IMO Press briefings.

International Maritime Organization (2002). *IMO adopts new regulations for bulk carriers.* IMO press briefings 2002.

Internet Ships Register of Lloyd's Register Fairplay. (2008). http://www.ships-register.com

Jansson, J. O. and Shneerson, D. (1982). The optimal ship size, *Journal of Transport Economics and Policy*, 16(3): 217-238.

Jansson, J. O. and Shneerson, D. (1987). A model of scheduled liner freight services: Balancing inventory cost against ship owner's costs, *The Logistics and Transportation Review*, 21(3): 195-215.

Jarque, C.M. and Bera, A.K. (1980) Cointegration and error correction: representation, estimation, and testing. *Econometrica* 55: 251-276.

Johansen, S. (1988) Statistical analysis of cointegration vectors, *Journal of Economic Dynamics and Control* 12: 231-254.

Johansen, S. (1991) Estimation and hypothesis testing of cointegration vectors in gaussian vector autoregressive models. *Econometrica* 59: 1551-1580.

Johansen, S. and Juselius, K. (1990). Maximum likelihood and inference on cointegration-with applications to the demand for money. *Oxford Bulletin of Economics and Statistics*, 52: 69-221.

Johansen, S. (1994). The role of the constant and linear terms in cointegration analysis of nonstationary time series, *Econometric Reviews* 13: 205-231.

Johansen, S. (1995a). *Likelihood-based Inference in Cointegrated Vector Autoregressive Models*, Oxford University Press, Oxford.

Kavussanos, M. G. (1996a). Comparisons of volatility in the dry-cargo ship sector: Spot versus time charters, and smaller versus larger vessels. *Journal of Transport Economics and Policy*, 1: 67-82.

Kavussanos, M. G. (1996b). Price risk modelling of different size vessels in the tanker industry. *Logistics and Transportation Review* 32: 161-176

Kavussanos, M. G. (1997). The dynamics of time-varying volatilities in different size second-hand ship prices of the dry-cargo sector. *Applied Economics,* 29: 433-443.

Kavussanos, M. G. and Nomikos, N. (1999). The forward pricing function of the shipping freight futures market. *Journal of Futures Markets*, 19, pp. 353-376.

Kavussanos, M. G. and Nomikos, N. K., (2000). Hedging in the freight futures market. *Journal of Derivatives*, 8: 41-58.

Kavussanos, M.G. and Alizadeh, A.H. (2001). Seasonality patterns in the dry bulk shipping spot and time-charter freight rates, *Transportation Research Part E*, 37, pp. 443-467.

Kavussanos, M.G., Menachof, D., and Visvikis, I.D. (2001): The unbiasedness hypothesis in the freight forward market, *the 2nd International Safety of Maritime Transport Conference*, Chios, Greece, 7-9 June.

Kavussanos, M.G. and Alizadeh, A.H. (2002a). The expectations hypothesis of the term structure and risk premia in dry bulk shipping freight markets. *Journal of Transport Economics and Policy,* 36(2):267-304.

Kavussanos, M..G, and Alizadeh A.H. (2002b). Efficient pricing of ships in the dry bulk sector of the shipping industry. *Maritime Policy and Management* 29(3): 303-330.

Kavussanos, M. G. (2003). Time varying risks among segments of the tanker freight markets. *Maritime Economics & Logistics,* 5: 227-250.

Kavussanos M.G., and Nomikos, N.K. (2003). Price discovery, causality and forecasting in the freight futures market. *Review of Derivatives Research*, 6: 203-230.

Kavussanos, M. G., Visvikis, I.D. and Batchelor, R. (2004). Over-the-counter forward contracts and spot price volatility in shipping. *Transport Research Part E: Logistics and Transportation Review*, 40(4):273-296. .

Kavussanos, M. G. and Visvikis, I.D. (2004) Market interactions in returns and volatilities between spot and forward shipping markets. *Journal of Banking and Finance* 28: 2015-2040.

Kavussanos, M. G., Visvikis, I. and Menachof, D. (2004). The unbiasedness hypothesis in the freight forward market: evidence from cointegration tests. *Review of Derivatives Research*, 7: 241-266.

Kirkaldy A.W. (1914) *British Shipping*, London: Kegan Paul Trench Trubner & Co. Ltd., reprinted August M.Kelly, New York, 1970.

Kiviet, J. F. (1986). On the rigor of some mis-specification tests for modelling dynamic relationships, *Review of Economic Studies* 53: 241-261.

Koopmans, T. C. (1939). Tanker freight rates and tankship building, *An Analysis of Cyclical Fluctuations.* Netherlands Economic Institute report No. 27. Haarlem, Holland.

Lahiri, K. and Moore, G.H. (1991). *Leading economic indicators: new approaches and forecasting records.* New York: the Press Syndicate of the University of Cambridge.

Lasdon, L.S., Waren, A.D., Jain, A. and Ratner, M. (1978). Design and testing of a generalised reduced gradient code for nonlinear programming. *ACM Transactions on Mathematical Software*. 4: 34-49.

Lim, S. D. (1994), Economies of Container Ship Size: A new evaluation, *Maritime Policy and Management*, 21(2): 149-160.

Lun, Y.H.V and Quaddus, M.A. (2009) An empirical model of the bulk shipping market. *International Journal of Transport Logistics,* 1 (1) : 37-54.

Lu, J., Marlow, P. B. and Wang, H.(2008) An analysis of freight rate volatility in dry bulk shipping markets. *Maritime Policy and Management*, 35(3): 237-251

Lütkepohl, H. (1991). *Introduction to Multiple Time Series Analysis*, Springer-Verlag, Berlin.

Lütkepohl, H. and Krätzig, M. (2004). *Applied Time Series Econometrics,* 1st edition, New York: Cambridge University Press.

Ljung, M. and Box, G. (1978) On a measure of lack of fit in time series models. *Biometrica* 65(2): 297-303.

MAN B&W Diesel A/S (2006). *Propulsion Trends in Bulk Carriers*, Copenhagen, Denmark, February 2006.

Mandelbrot, B. (1967). The Variation of Some Other Speculative Prices, *Journal of Business*, University of Chicago Press, 40, page 393.

McConville, J.(1998). *Economics of Maritime Transport, Theory and Practice.* London: Witherby & Co Ltd.

Ministry of Commerce of China: *http://zhs.mofcom.gov.cn/tongji.shtml*

Nelson, D. B. (1991).Conditional heteroskedasticity in asset returns: A new approach, *Econometrica* 59: 347-370.

National Bureau of Statistics of China: *http://www.stats.gov.cn/tjsj/ndsj/*

Newey, W.K. and West, K. (1987) A simple positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix. *Econometrica,* 55: 703-708.

Newcastle Port Corporation: *http://www.newportcorp.com.au/page_archive.aspx?pageID=173*

Norman, V. D. (1979). *The Economics of Bulk Shipping.* Institute for Shipping Research, Bergen, Norway.

ONADA, http://www.oanda.com/currency/

Osterwald-Lenum, M. (1992). A note with the quantiles of the asymptotic distribution of the ML cointegration rank test statistics. *Oxford Bulletin of Econometrics and Statistics* 54: 461-472.

Pagan, A.(1996). The econometrics of financial markets. *Journal of Empirical Finance.* 3: 15-102.

Palm, F. (1996). GARCH models of volatility, in G. Maddala&C. Rao (eds.), *Handbook of Statistics*, 14: 209-240. Elsevier, Amsterdam.

Pesaran, M.H. and Shin, Y. (1998). Generalised impulse response analysis in linear multivariate models. *Economics Letters*, 58, 17–29.

Phillips, P.C.B. and Perron, P. (1988). Testing for a unit root in time series regressions. *Biometrica* 75: 335-346.

Ronen, D. (1982). The effect of oil price in the optimal speed of ships. *Journal of the Operational Research Society*, 33: 1035-1040.

RINA (1990-2006). *The Significant Ships 1990 to 2006.* UK: The Royal Institute of Naval Architects.

Reimers, H. (1992). Comparisons of tests for multivariate cointegraiton. *Statistical Papers* 33: 335-359.

Scarsi, R. (2007), The bulk shipping business: market cycles and shipowners’ biases, *Maritime Policy and Management*, 34(6): 577-590.

Schwarz, G. (1978). Estimating the dimension of a model. *Annals of Statistics* 6: 461-464.

Schwartz, E. (1997).The stochastic behaviour of commodity prices: implications for valuation and hedging. *Journal of Finance* LII: 923-973.

Schwager, J.D.(1996). *Technical Analysis.* New York: John Wiley & Sons.

Schwert, G. W. (1989). Why does stock market volatility change over time? *Journal of Finance*, vol. 44(5), pp. 1115-53.

Shimojo, T. (1979). *Economics Analysis of Shipping Freights.* Kobe: Kobe University.

Sims, C. (1980). Macroeconomics and reality. *Econometrica,* 48: 1-48.

Spencer, J. (2004). Present and future research and developments in Shipping. *ABS Technical Papers 2004,* 287-302.

Stiglitz, J. E. (2002). *Globalization and its Discontents.* New York: Norton.

Stopford, M. (2009). *Maritime Economics.* 3rd Edition, London: Routledge.

Strandenes, S. P. (1984). Price Determination in the time charter and second hand markets. Discussion paper 0584, Norwegian School of Economics and Business Administration, Bergen, Norway

Strandenes, S.P. and Wergeland, T. (1981). Ecotank. *Working paper*, SAF, Norwegian School of Economics and Business Administration.

Sys, C., Blauwens, G., Omey, E., Van De Voorde, E. and Witlox, F. (2008). In search of the link between ship size and operations. *Maritime Policy and Management*, 31(4): 435-463.

Taniguchi, M., and Kakizawa, Y. (2000) *Asymptotic Theory of Statistical Inference for Time Series*. New York: Springer-Verlag.

Talley, W. K. and Pope, J. (1988). Inventory costs and optimal ship size. *The Logistics and Transportation Review*, 24: 107-120.

Taylor, S. J. (1986). *Modelling Financial Time Series,* New York: John Wiley & Sons, Chichester.

Tinbergen, J. (1959). Tonnage and freight. In: *Jan Tingergen Selected Papers,* eds. L.H.Klaassen et al. Amsterdam: North-Holland Publishing Company.

Torroja, T. and Alonso, F. (1999). *Developments in Computer Aided Ship Design and Production*, Trans. The Royal Institute of Naval Architects.

Tsolakis, S. (2005). *Econometric Analysis of Bulk Shipping Markets-Implications for Investment Strategies and Financial Decision-Making,* Doctoral thesis of Erasmus University of Rotterdam.

Tvedt, J. (2003). Shipping market models and the specification of freight rate processes. *Maritime Economics and Logistics*, 5(4): 327-346.

UNCTAD. (1970-2008). *The Review of Maritime Transport,* various. Geneva: United Nations Conference on Trade and Development.

Veenstra, A.W. and Franses, P.H. (1997). A co-integration approach to forecasting freight rates in the dry bulk shipping sector, *Transportation Research Part A: Policy and Practice,* 31(6), pp. 447-458.

Veenstra, A. W. (1999). *Quantitative Analysis of Shipping Markets.* T99/3, TRAIL Thesis Series, the Netherlands: Delft University Press.

Veenstra, A. W. and Ludemaz, M.W. (2006). The relationship between design and economic performance of ships. *Maritime Policy and Management*, 33(2): 159-171.

Watson, D.G..M. (1998). *Practical Ship Design*. 81-230. 1st version, UK: Elsevier Science Ltd.

Wergeland, T. (1981). Norbulk: *A simulation model of bulk freight rates*. Working paper no. 12. Norwegian School of Economics and Business Administration.

Wijnolst, N., van de Hoeven, Kleijergt, C.J., and Sjobris, A. (1993). *Innovation in Shortsea Shipping,* 24-33. The Netherlands: Delft University Press.

White, H. (1980). A heteroskedastic-consistent covariance matrix estimator and a direct test for heteroskedasticity, *Econometrica* 48: 817-838.

White, H. (2000). A reality check for data snooping. *Econometrica* 68, 1097-1126.

Zannetos, Z. (1966). *The Theory of Oil Tankship Rates*. Boston: MIT Press.

Zellner, A. (1962). An efficient method of estimating seemingly unrelated regressions and tests of aggregation bias, *Journal of the American Statistical Association* 57: 348-368.

Appendix A. Methodology

This part describes mainly the econometric models used in various chapters, for various variables of interest, such as freight rates, time charter rates and ship prices. It also presents other methods applied in some chapters to analyze impacts of technology into economic performance of ships.

Economic processes, involving a number of economic variables and relations between them, can be studied by time series analysis. There are two main goals of time series analysis. One is to identify the nature of the phenomenon represented by time series, and the other is to forecast future values of the time series variable.

In the following topics, we will at first discuss data properties in time series, including data handling, transformation and stationarity test, and then we will introduce a general class of models that can be used to represent time series data and generate predictions, including autoregressive and moving average models, vector autoregressive models and vector error correction models. Some attention has been paid to the specification, estimation, evaluation and statistical properties of these models, which are of great importance to the selection of an appropriate model into studying properties of time series and relations between economic variables. Finally, some methods are presented, employed to estimate the power installed and the resistance of ships.

A-1. Data analysis in time series

The data obtained from a specific source may not be in precisely the form to be used in the analysis. Data formats and codings can be or often are different when the data come from different sources. Therefore, it is usually necessary to arrange them in a uniform way in the software, for instance, in EVIEWS. Still it may be useful to make adjustments before the econometric analysis begins. For example, to avoid numerical problems it may be helpful to pay attention to a roughly similar order of magnitude in the actual time series numbers. The required operations for making the data more homogenous are often easy to perform with the software tool available.

A-1.1. Data transformation

The first step in building dynamic econometric models entails a detailed analysis of the characteristics of the individual time series variables involved, which have to be considered in modelling the time series or a system of time series of related variables.

In our analysis, time series are transformed by taking natural logarithms. There are several reasons for such transformation. Firstly, many economic time series are characterized as non-stationarity. However, in some cases simple transformations can move a series closer to stationarity. In such a case, a logarithmic transformation may be helpful to stabilize the variance. Secondly, the first differences of the logs are roughly the rates of change of the series, and in some cases called returns, which have economic implications for market participants. Thirdly, by transformation, an exponential trend in time series becomes linear and thus it is easier to make the analysis in detail.

A-1.2. Stationarity and the unit root test

Before modelling time series, it is necessary to test the stationarity of the time series variables, because models containing non-stationary variables will often lead to a problem of spurious regression.

A stochastic process y_t is called stationary if

$$E(y_t) = \mu_y$$
$$\mathrm{var}(y_t) = E[(y_t - \mu_y)^2] = \gamma_0 \quad \text{(A.1)}$$
$$Cov(y_t, y_{t-h}) = E(y_t - \mu_y)(y_{t-h} - \mu_y) = \gamma_h$$

for all $t \in T$ and all integers h such that $t - h \in T$.

As can be seen in Equation (A.1), there are three conditions for a stationary process. The first condition means that all members of a stationary stochastic process have the same constant mean. Hence, a time series generated by a stationary stochastic process must fluctuate around a constant mean and does not have a trend, for example. The second ensures that the variances are also time invariant because they are not dependent on time t. The third indicates that covariances do not depend on t, but just on the distance in time h of the two members of the process.

When discussing stationary and non-stationary time series, it is necessary to test for the presence of unit roots in order to avoid the problem of spurious regression, because regressions involving the non-stationary series can falsely imply the existence of a meaningful economic relationship, unless it combines with other non-stationary series to form a stationary cointegration relationship. If a variable contains a unit root, then it is non-stationary.

In principle it is important to test the order of integration of each variable in a model, to establish whether it is non-stationary and how many times the variable needs to be differenced to result in a stationary series. A time series is said to be integrated of order d $(I(d))$, if first differences have to be applied d times to make the process stationary or asymptotically stationary. A stationary process y_t is sometimes called $I(0)$.

Denoting the differencing operator by Δ (i.e., $\Delta = 1-L$, so that for a time series or stochastic process y_t, we have $\Delta \log y_t = \log y_t - \log y_{t-1}$, the process y_t is said to be $I(d)$, if $\Delta^d y_t$ is stationary, whereas $\Delta^{d-1} y_t$ is still non stationary. An $I(d)$ process with $d \geq 1$ is often called a unit root process, or it is said to have a unit root. There are several ways of testing for the presence of a unit root. Dickey-Fuller test (Dickey and Fuller (1979)), the Phillips-Perron (PP) Test (Phillips and Perron (1988)) and The Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) Test (The KPSS (1992)) will be introduced here, because these three are used in our analysis.

- **The Dickey-Fuller (ADF) Test**

The emphasis here will be the Dickey-Fuller (DF) approach, see, to testing the null hypothesis that a series does contain a unit root against the alternative of stationarity. Because of the simplicity or more general nature, the DF tests tend to be more popular.

Consider a simple AR(1) process:

$$y_t = \rho y_{t-1} + x_t^{'} \delta + \varepsilon_t \quad \text{(A.2)}$$

Where x_t are optional exogenous regressors which may consist of constant, or a constant and trend, ρ and δ are parameters to be estimated, and ε_t is assumed to be white noise. If $|\rho| \geq 1$, y_t is a nonstationary series and the variance of y_t increases with time and approaches infinity. If $|\rho| < 1$, is a (trend-)stationary series. Thus, the hypothesis of (trend-) stationarity can be evaluated by testing whether the absolute value of is strictly less than one. The unit root tests that EVIEWS provides generally test the null hypothesis

$H_0 : \rho = 1$ against the one-sided alternative: $H_1 : \rho < 1$

The Augmented Dickey-Fuller (ADF) Test

The standard DF test is carried out by estimating Equation (A.2) after subtracting y_{t-1} from both sides of the equation:

$$\Delta y_t = \alpha y_{t-1} + x_t^{'} \delta + \varepsilon_t \quad \text{(A.3)}$$

Where $\alpha = \rho - 1$. The null and alternative hypotheses may be written as,

$$H_0 : \alpha = 0$$
$$H_1 : \alpha < 0 \quad \text{(A.4)}$$

And evaluated using the conventional t -ratio for α:

$$t_\alpha = \hat{\alpha} / (se(\hat{\alpha})) \quad \text{(A.5)}$$

Where $\hat{\alpha}$ is the estimate of α, and $se(\hat{\alpha})$ is the coefficient standard error.

Dickey and Fuller (1979) show that under the null hypothesis of a unit root, this statistic does not follow the conventional Student's *t*-distribution, and they derive asymptotic results and simulate critical values for various test and sample sizes. More recently, MacKinnon (1991, 1996) implements a much larger set of simulations than those tabulated by Dickey and Fuller. In addition, MacKinnon estimates response surfaces for the simulation results, permitting the calculation of Dickey-Fuller critical values and p-values for arbitrary sample sizes. The more recent MacKinnon critical value calculations are used by Eviews in constructing test output.

The simple Dickey-Fuller unit root test described above is valid only if the series is an AR(1) process. If the series is correlated at higher order lags, the assumption of white noise disturbances ε_t is violated. The Augmented Dickey-Fuller (ADF) test constructs a parametric correction for higher-order correlation by assuming that the y_t series follows an AR(p) process and adding p lagged difference terms of the dependent variable y_t to the right-hand side of the test regression:

$$\Delta y_t = \alpha y_{t-1} + x_t^{'} \delta + \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + v_t \quad \text{(A.6)}$$

This augmented specification is then used to test Equation (A.3) using the t -ratio (A.5).

In performing an ADF test, two practical issues are faced. First, you must choose whether to include exogenous variables in the test regression. There is a choice of including a constant, a constant and a linear time trend, or neither in the test regression. One approach would be to run the test with both a constant and a linear trend since the other two cases are just special cases of this more general specification. However, including irrelevant regressors in the regression will reduce the power of the test to reject the null of a unit root. The standard recommendation is to choose a specification that is a plausible description of the data under both the null and alternative hypotheses. See Hamilton (1994) for more discussion.

Second, you will have to specify the lag length to be added to the test regression. The usual advice is to include a number of lags sufficient to remove serial correlation in the residuals. Eviews provides both automatic and manual lag length selection options.

- **The Phillips-Perron (PP) Test**

Phillips and Perron (1988) propose an alternative (nonparametric) method of controlling for serial correlation when testing for a unit root. The PP method estimates the non-augmented DF test equation, and modifies the t -ratio of the coefficient so that serial correlation does not affect the asymptotic distribution of the test statistic. The PP test is based on the statistic:

$$\tilde{t}_\alpha = t_\alpha \left(\frac{\gamma_0}{f_0} \right)^{1/2} - \frac{T(f_0 - \gamma_0)(se(\hat{\alpha}))}{2 f_0^{1/2} s} \quad \text{(A.7)}$$

Where $\hat{\alpha}$ is the estimate of α, and t_α the t-ratio of α, $se(\hat{\alpha})$ is the coefficient standard error, and s is the standard error of the test regression. In addition, γ_0 is a consistent estimate of the error variance in Equation (A.3) (calculated as $(T-k)s^2/T$, where k is the number of regressions). The remaining term f_0 is an estimator of the residual spectrum at frequency zero.

There are two choices you will have when performing the PP test. First, you must choose whether to include a constant, a constant and a linear time trend, or neither, in the test regression. Second, you will have to choose a method for estimating f_0. Eviews supports estimators for based on kernel-based sum-of-covariances, or on autoregressive spectral density estimation.

The asymptotic distribution of the PP modified t-ratio is the same as that of the ADF statistic. Eviews reports MacKinnon lower-tail critical and *p*-values for this test.

A-2. Univariate time series analysis

This section has emphasized the standard representation of economic time series as that of a univariate linear stochastic process, specifically as being a member of the class of ARIMA models popularized by Box and Jenkins (1976). For detailed theoretical treatments, see, for example, Brockwell and Davis (1987), Hamilton (1994), Fuller (1996) or Taniguchi and Kakizawa (2000).

Because most economic time series exhibit serial correlation, there are some simple parametric models that have been used frequently to describe economic time series. In this section we will briefly discuss the mixed autoregressive moving average (ARMA) models.

A-2.1. Model specification

Basically, an ARMA model combines the ideas of AR and MA models into a compact form so that the number of parameters used is kept small.

- **An ARMA model**

A time series y_t follows an ARMA(1,1) model if it satisfies,

$$y_t - \phi_1 y_{t-1} = \phi_0 + \varepsilon_t + \theta_1 \varepsilon_{t-1} \qquad \text{(A.8)}$$

Where ε_t is a white noise series. The left-hand side of equation is the AR component of the model and the right-hand side gives the MA component. The constant term is ϕ_0. For this model to be meaningful, we need $\phi_1 = \theta_1$; otherwise, there is a cancellation in the equation and the process reduces to a white noise series.

A general ARMA(p,q) model is in the form,

$$y_t = \phi_0 + \sum_{i=1}^{p} \phi_i y_{t-i} + \sum_{j=0}^{q} \theta_j \varepsilon_{t-j} \qquad \text{(A.9)}$$

Where ε_t is a white noise series; p and q are non-negative integers. The AR and MA models are special cases of the ARMA (p,q) model. Using the back-shift operator *L*, the model can be written as

$$(1-\phi_1 L - \cdots - \phi_p L^p) y_t = \phi_0 + (1-\theta_1 L - \cdots - \theta_q L^q)\varepsilon_t \qquad \text{(A.10)}$$

The polynomial $(1-\phi_1 L - \cdots - \phi_p L^p)$ is the AR polynomial of the model. Similarly, $(1-\theta_1 L - \cdots - \theta_q L^q)$ is the MA polynomial. We require that there are no common factors between the AR and MA polynomials; otherwise the order (p,q) of the model can be reduced. Like a pure AR model, the AR polynomial introduces the characteristic equation of an ARMA model. If all of the solutions of the characteristic equation are less than 1 in absolute value, then the ARMA model is weakly stationary. In this case, the unconditional mean of the model is $E(y_t) = \phi_0 / (1-\phi_1 - \cdots - \phi_p)$.

The process is stable and stationary if $\phi(z) \neq 0$ for $|z| \leq 1$, and it is invertible if $\theta(z) \neq 0$ for $|z| \leq 1$. If the process is stable, it has a pure MA representation from which the autocorrelations can be obtained. Conversely, if the process is invertible, it has a pure AR representation. For the mixed processes with nontrivial AR and MA parts, the autocorrelations and partial autocorrelations both do not have a cutoff point but taper off to zero gradually.

The information criteria are used to select an appropriate ARMA models, including the Schwarz Bayesian Information Criterion (Schwarz, 1978, also known as SC) and Akaike Information Criterion (Akaike, 1973, known as AIC). Typically, for some pre-specified positive integers P and Q, one computes SC or AIC for ARMA (p, q) models, where $0 \le p \le P$ and $0 \le q \le Q$, and selects the model that gives the minimum SBIC or AIC.

The generalizations of the corresponding criteria are as follows.

$$AIC(n) = \log \tilde{\sigma}_{\varepsilon}^2(n) + \frac{2}{T} n$$
$$SC(n) = \log \tilde{\sigma}_{\varepsilon}^2(n) + \frac{\log T}{T} n \tag{A.11}$$

Where $\tilde{\sigma}_{\varepsilon}^2(n) = T^{-1}\sum_{t=1}^{T}\hat{\varepsilon}_t(n)^2$ is the error variance estimator based on the OLS residuals $\hat{\varepsilon}_t(n)$ from an AR model of order n. These results are not only hold for $I(0)$ processes but also for $I(1)$ processes with cointegrated variables, see Paulsen (1984).

- **An ARMA-X model**

An ARMAX model is an autoregressive moving average (ARMA) model for an endogenous dependent variable with additional explanatory exogenous variables. Bierens (1987) develops the estimation and testing methodology for such a model. The ARMA part is considered as a special case of ARMAX with no regressor by Greene (1990). Harvey (1990) and Franses (1991) treat the ARMAX problem as an extension of ARIMA modelling because the disturbances are generated by an ARIMA ($p,1,q$) process. In other words, an ARMAX ($p,1,q,z$) model can be explicitly represented as

$$y_t = \alpha_0 + \sum_{i=1}^{p}\alpha_i y_{t-i} + \sum_{k=1}^{s}\gamma'_{r,k} Z_{t-k} + \sum_{j=0}^{q}\theta_j \varepsilon_{t-j} \tag{A.12}$$

Where α_0 is the constant term, Z_t is the vector of exogenous variables, and ε_t are white noise terms. The γ'_k vector is the $1\times r$ vector of parameters, Z_t is the $(r \times 1)$ vector of exogenous variables.

A-2.2. Model estimation

Once an ARMA (p, q) model is specified, its parameters can be estimated by either the conditional or exact likelihood method. It is still possible to set up the Gaussian likelihood function and use ML or, if the conditional distributions of the observations are not Gaussian (normally distributed), quasi-ML estimation. The joint density of the random variables $y_1, \cdots y_T$ may be written as a product of conditional densities.

$$f(y_1, \cdots y_T) = f(y_1)\cdot f(y_2 | y_1) \cdots f(y_T | y_{T-1}, \cdots y_1) \tag{A.13}$$

Hence, the log-likelihood function for an ARMA(p,q) process $\phi(L) y_t = \theta(L)\varepsilon_t$ has the form

$$l(\phi_1, \cdots \phi_p, \theta_1 | \theta_2, \cdots \theta_q) = \sum_{t=1}^{T} l_t(\cdot) \tag{A.14}$$

Where $l_t(\cdot) = -\frac{1}{2}\log 2\pi - \frac{1}{2}\log \sigma_{\varepsilon}^2 - (\phi(L)^{-1}\theta(L) y_t)^2 / 2\sigma_{\varepsilon}^2$

If the conditional distributions of y_t are normally distributed. Maximizing the log-likelihood results in ML or quasi-ML estimators in the usual way. The optimization problem is highly nonlinear and should observe inequality restrictions that ensure a unique and stable ARMA representation. Generally, the resulting estimators will then have an asymptotic normal distribution, which may be used for inference. Because iterative algorithms usually have to be used in optimizing the log likelihood, start-up values for the parameters are required. Different procedures may be used for this purpose and they are dependent on the model under consideration.

The estimation of ARMAX model should firstly ensure that the dependent variable y_t must exhibit a stationary process. Furthermore, the ARMAX model requires that all exogenous variables also show stationary time series patterns. In comparison to ARMA model, the ARMAX model takes the exogenous variables into account, assuming that these variables are not dependent only on endogenous variables, so the forecasting method does not solely depend on historical data.

A-2.3. Model checking

Once a model has been specified, a range of diagnostic tools are available for checking its adequacy. Many of them are based on the model residuals. Plotting the residual series of a time series model is an important way to detect possible model deficiencies. For example, serial correlation, heterogenous variances, or structural breaks may exhibit in the residual series.

For spotting unusual residuals, a standardization of the residuals may be useful before plotting them. Denoting the residual series by ε_t, we obtain the standardized residuals by subtracting the mean and dividing by the standard deviation; that is, the standardized residuals are

$$e_t = (\hat{\varepsilon}_t - \bar{\hat{\varepsilon}}) / \tilde{\sigma}_\varepsilon \qquad \text{(A.15)}$$

Where $\tilde{\sigma}_\varepsilon^2 = T^{-1}\sum_{t=1}^{T}(\hat{\varepsilon}_t - \bar{\hat{\varepsilon}})^2$ with $\bar{\hat{\varepsilon}} = T^{-1}\sum_{t=1}^{T}\hat{\varepsilon}_t$

Alternatively, an adjustment for degrees of freedom may be used in the variance estimator. Moreover, the autocorrelations and partial autocorrelations of the residuals may be worth looking at because these quantities contain information on possibly remaining serial dependence in the residuals.

Similarly, the autocorrelations of the squared residuals may be informative about possible conditional heteroskedasticity. If there is no leftover autocorrelation or conditional heteroskedasticity, the autocorrelations and partial autocorrelations should be within a $\pm 2/\sqrt{T}$ -band around zero with a very few exceptions. Therefore, autocorrelations and partial autocorrelations associated with low lags that reach outside the $\pm 2/\sqrt{T}$ -band are suspicious and give rise to concern about the adequacy of the model, see Lütkepohl (1991).

Several statistical tests are available for diagnostic purposes. Jarque and Bera(1987) have proposed a test for non-normality. Breusch-Godfrey test can be used to examine the autocorrelation, details can be seen in Harvey (1990) and Kiviet (1986). Engle's (1982) ARCH-LM test can be used to check the conditional heteroskedasticity.

A-2.4. Forecasting ARMA model

If a suitable model of a given time series has been found, it can be used for forecasting the future development of the variable under consideration. AR processes are particularly easy to use for this purpose. Neglecting deterministic terms and assuming an AR(*p*),

$$y_t = \alpha_1 y_{t-1} + \cdots + \alpha_p y_{t-p} + \varepsilon_t \qquad \text{(A.16)}$$

Where ε_t are error terms, generated by an independent rather than just uncorrelated white noise process, we find that the optimal (minimum MSE) 1-step forecast in period T is the conditional expectation

$$y_{T+1|T} = E(y_{T+1} | y_T, y_{T-1}, \cdots) = \alpha_1 y_T + \cdots + \alpha_p y_{T+1-p} \qquad \text{(A.17)}$$

Forecasts for larger horizons h>1 may be obtained recursively as

$$y_{T+h|T} = \alpha_1 y_{T+h-1|T} + \cdots + \alpha_p y_{T+h-p|T} \qquad \text{(A.18)}$$

Where $y_{T+j|T} = y_{T+j}$ for $j \le 0$

The corresponding forecast errors are

$$\begin{aligned} & y_{T+1} - y_{T+1|T} = \varepsilon_{T+1,} \\ & \cdots \\ & y_{T+h} - y_{T+h|T} = \varepsilon_{T+h} + \phi_1 \varepsilon_{T+h} + \cdots + \phi_{h-1} \varepsilon_{T+1} \end{aligned} \tag{A.19}$$

Where it is easy to see by the successive substitution that the ϕ_j s are just the coefficients of the MA representation of the process if the process is stationary and, hence, the MA representation exists. The MSE of an h-step forecast is

$$\sigma_y^2(h) = E((y_{T+h} - y_{T+h|T})^2) = \sigma_\varepsilon^2 \sum_{j=0}^{h-1} \phi_j^2 \tag{A.20}$$

In the non-stationary case, for example, y_t is $I(d)$ with $d > 0$, the ϕ_j s are not coefficients of an MA representation, of course, and they will not converge to zero for $j \to \infty$. As a consequence, the forecast MSEs will not converge for $h \to \infty$, but will be unbounded. Hence, the length of the forecast intervals will also be unbounded as $h \to \infty$.

For $I(d)$ variables with $d > 0$, there is also another possibility to compute the forecasts. Suppose y_t is $I(1)$ so that y_t is stationary. Then we can utilize the fact that

$$y_{T+h} = y_T + \Delta y_{T+1} + \cdots + \Delta y_{T+h} \tag{A.21}$$

Thus, to forecast y_{T+h} in period T, we just need to get forecasts of the stationary variables y_{T+j}, $j = 1, \cdots h$ and add these forecasts to y_T to get the forecast of y_{T+h}. This forecast is identical to the one obtained directly from the levels AR(*p*) model. If the time series is a mixed ARMA process with infinite AR representation, this representation can in principle be used for forecasting. For practical purposes it has to be truncated at some finite lag length.

A-3. Multivariate time series analysis

In constructing a model for a specific purpose, we have to decide what variables should be included in the analysis. In some cases, many variables are related to the presently considered ones and, hence, they could be included in a model under consideration.

Vector autoregressive (VAR) processes are a suitable model class for describing a small or a moderate set of time series variables. In these models all variables are often treated as being a priori endogenous, and allowance is made for rich dynamics. Restrictions are usually imposed with statistical techniques instead of prior beliefs based on uncertain theoretical considerations. A situation of special interest arises if several variables are driven by a common stochastic trend, as may occur in some of the example series. Following Granger (1981) and Engle & Granger (1987), variables are called cointegrated if they have a common stochastic trend. If cointegrating relations are present in a system of variables, the VAR form is not the most convenient model setup. In that case it is useful to consider specific parameterizations that support the analysis of the cointegration structure. The resulting models are known as vector error correction models (VECMs) or vector equilibrium correction models.

A-3.1. The vector autoregressive model

In this part, we introduce the basic theory behind the vector autoregressive model, including the model specification, estimation, checking and forecasting.

- **Model specification**

The use of VAR models has been recommended by Sims (1980) as an efficient alternative to verify causal relationships in economic variables and to forecast their evolution. Given y_t a set of K time series variables $y_t = (y_{1t,} \cdots y_{kt})'$, the basic model of order p (VAR(p)) has the form,

$$y_t = \sum_{i=1}^{p} \phi_i y_{t-i} + \varepsilon_t \tag{A.22}$$

Where the ϕ_i is the $k \times k$ coefficient matrix, and $\varepsilon_t = (\varepsilon_{1t,} \cdots \varepsilon_{kt})'$ is an unobserved error term. It is usually assumed to be a zero-mean vector of white noise processes with positive definite contemporaneous covariance matrix Σ and zero covariance matrices at all other lags.

The process is stable if

$$\det(I_k - \phi_1 z - \cdots - \phi_p z^p) \neq 0 \quad \text{for} \quad |z| \leq 1 \tag{A.23}$$

That is, the polynomial defined by the determinant of the autoregressive operator has no roots in and on the complex unit circle. On the assumption that the process has been initiated in the infinite past (*t* = 0,±1,±2, . . .), it generates stationary time series that have time-invariant means, variances, and covariance structure.

Deterministic terms

Several extensions of the basic VAR models are usually necessary to represent the main characteristics of a data set of interest. Sometimes, it is clear that including deterministic terms, such as an intercept, a linear trend term, or seasonal dummy variables, may be required for a proper representation of the time series. One way to include deterministic terms is simply to add them to the stochastic part.

$$y_t = \mu_t + x_t \tag{A.24}$$

Here μ_t is the deterministic part, and x_t is a stochastic process that may have a VAR representation. On the assumption, for instance, μ_t is a linear trend term, that is $\mu_t = \mu_0 + \mu_1 t$, such a model following VAR(p) representation for y_t:

$$y_t = \mu_0 + \mu_1 t + \sum_{i=1}^{p} \phi_i y_{t-i} + \varepsilon_t \tag{A.25}$$

The Equation (A.25) may be viewed as the basic model without restrictions for μ_i (i=0,1). It is sometimes advantageous in theoretical derivations that, in Equation (A.24), a clear partitioning of the process in a deterministic and a stochastic component can be available. In some instances it is desirable to subtract the deterministic term first because the stochastic part is of primary interest in econometric analyses. Then the analysis can focus on the stochastic part containing the behavioral relations.

Choice of the deterministic term

A proper choice of the deterministic term is important. If a linear time trend is regarded as a possibility, one could just include such a term in the process. In Doornik, Hendry & Nielsen (1998), small sample and asymptotic evidence is presented that, if a deterministic trend actually present in the time series is not taken into account, it may result in major size distortions, and their study confirms that including an unnecessary trend term may result in a loss of power, see also Hubrich et al. (2001).

Therefore, it is worthwhile to invest some effort in a proper trend specification. There are also statistical procedures that can help to determine the deterministic components. Specifically, tests are proposed in Johansen (1994, 1995a) for hypotheses regarding the deterministic term within his Gaussian likelihood framework. Apart from dummy variables, the most general deterministic term in the VAR form of the processes considered is $\mu_0 + \mu_1 t$. Because the ML estimators of the corresponding models can be obtained easily, LR tests are obvious possibilities. The test statistics have asymptotic χ^2-distributions under the null hypothesis. As usual, the Gaussian framework is convenient in deriving the tests, whereas the limiting distributions of the test statistics remain valid under more general conditions.

Exogenous variables

Further generalizations of the model are often desirable in practice. For example, one may wish to include further stochastic variables in addition to the deterministic part.

$$y_t = \mu_t + \sum_{i=1}^{p} \phi_i y_{t-i} + \sum_{j=0}^{q} \gamma_j Z_{r,t-j} + \varepsilon_t \tag{A.26}$$

Where μ_t is the deterministic term, ϕ_i is the $k \times k$ matrix, Z_t is the $(r \times 1)$ vector of exogenous variables, and ε_t are error terms.

Including exogenous variables may be problematic for inference and analysis purposes unless the variables satisfy exogeneity requirements. Different concepts of exogeneity have been considered in the literature, see Engle, Hendry & Richard (1983).

A set of variables Z_t is said to be weakly exogenous for a parameter vector of interest, for instance γ, if estimating γ within a conditional model (conditional on Z_t) does not entail a loss of information relative to estimating the vector in a full model that does not condition on Z_t.

Furthermore, Z_t is said to be strongly exogenous if it is weakly exogenous for the parameters of the conditional model and forecasts of y_t can be made conditional on Z_t without loss of forecast precision.

Finally, Z_t is termed super exogenous for γ if Z_t is weakly exogenous for γ and policy actions that affect the marginal process of Z_t do not affect the parameters of the conditional process.

The VAR model incorporating exogenous variables can be called as the VARX model. The VARX model should in principle be the best performer because they incorporate not only the endogenous dynamics, but also additional information from the exogenous variables. Comparing the performance of VAR and VARX, we control for the dimensionality in order to determine the contribution of the inclusion of Z_t. The Schwarz Bayesian Information Criterion (SC; Schwarz, 1978), Akaike Information Criterion (AIC; Akaike,1973) and LR test were used to determine the lag length in the models and to select the most appropriate exogenous variables to be incorporated in the models. The vector Z_t is observed at the time of the forecast values produced, hence forecasts for exogenous variables are not necessary.

Determining the autoregressive order

In determining the lag order of a dynamic model, in principle the same procedures are available that were already discussed for univariate models. In other words, sequential testing procedures and model selection criteria may be applied.

It is useful to focus on the VAR form (A.22) at this stage because the cointegrating rank *r* is usually unknown when the choice of the lag order *p* is made. Generalised versions of the criteria discussed in the univariate case are available to determine a suitable model order. The general approach is again to fit VAR(*m*) models with orders $m = 0, \ldots, p_{max}$ and to choose an estimator of the order *p* that minimizes the preferred criterion.

The following criteria are direct generalizations of the corresponding criteria discussed for univariate processes:

$$\begin{aligned} AIC(m) &= \log\left|\tilde{\Sigma}_\varepsilon(m)\right| + \frac{2}{T} mK^2 \\ SC(m) &= \log\left|\tilde{\Sigma}_\varepsilon(m)\right| + \frac{\log T}{T} mK^2 \end{aligned} \tag{A.27}$$

Where $\tilde{\Sigma}_\varepsilon(m) = T^{-1} \sum_{t=1}^{T} \hat{\varepsilon}_t \hat{\varepsilon}_t'$ is the residual covariance matrix estimator for a model of order *m*. T is the sample size and K is the number of time series variables in the VAR model.

- **Model estimation**

The estimation of a VAR model is relatively simple. The *K* equations of the VAR model (A.24) may be estimated separately by ordinary least squares (OLS). The resulting estimator has the same efficiency as a generalised LS (GLS) estimator, as shown by Zellner (1962). The detailed estimation procedure can be seen in Lütkepohl (1991).

Due to the particular structure of VAR models, where all equations have the same number of explanatory variables, VAR models are often over-parameterized. While it may seem to improve estimation efficiency to delete statistically insignificant coefficients and this can only be done if the vector time series process y_t is stationary. As soon as coefficients are set equal to zero, the possibility arises that the equations may not have the same set of regressors anymore. The estimation of the VAR model is then made by the seemingly unrelated regression (SUR) technique, instead of the OLS approach, see Zellener(1962). In principal, to the extent that the errors across equations of the VAR model are contemporaneously correlated and the independent variables in separate equations are uncorrelated, the SUR estimates of the covariance matrix would be more accurate, see Lahiri and Moore (1992).

- **Model checking**

Many statistical tools exist for checking whether a given VAR model provides an adequate representation of the time series. As in the univariate case, many of them are based on the residuals of the final model. Some of them are applied to the residuals of individual equations and others are based on the full residual vectors.

If model defects such as residual autocorrelation or ARCH effects are detected at the checking stage, this is usually regarded as an indication that the model is a poor representation. Efforts are then made to find a better representation by adding other variables or lags to the model, by including nonlinear terms or changing the functional form, by modifying the sampling period, or getting other data.

A descriptive analysis of the model residuals is at least partly based on the individual series. Therefore the graphs considered for checking the univariate time series are relevant here as well. For example, plots of standardized residual series and squared residuals may be informative. Additionally, a range of diagnostic tests is available for checking the model assumptions and properties formally. Tests for autocorrelation, nonnormality, and conditional heteroskedasticity are considered. Jarque and Bera(1987) have proposed a test for non-normality. Breusch-Godfrey test can be used to examine the autocorrelation. Engle’s (1982) ARCH-LM test can be used to check the conditional heteroskedasticity. Details of those testing procedures can be found in Lütkepohl and Krätzig (2004).

- **Forecasting VAR model**

Once a VAR model has been found, it may be used for forecasting as well as economic analysis. Forecasting vector processes is completely analogous to forecasting univariate processes, as discussed in the previous section. The levels VAR form (A.22) is particularly convenient to use in forecasting the variables *yt* . We will again initially ignore deterministic terms and exogenous variables. Moreover, it is assumed first that the process parameters are known. Suppose the ε_t is generated by an independent white noise process. In that case the minimum mean-squared error (MSE) forecast is the conditional expectation. For example, at forecast origin *T*, an *h*-step ahead forecast is obtained recursively as

$$y_{T+h|T} = \phi_1 y_{T+h-1|T} + \cdots + \phi_p y_{T+h-p|T} \tag{A.28}$$

Where $y_{T+j|T} = y_{T+j}$ for $j \le 0$. The corresponding forecast error is

$$y_{T+h} - y_{T+h|T} = \varepsilon_{T+h} + \varphi_1 \varepsilon_{T+h-1} + \cdots + \varphi_{h-1} \varepsilon_{T+1} \tag{A.29}$$

Where it can be shown by successive substitution that

$$\varphi_s = \sum_{j=1}^{s} \varphi_{s-j}\phi_j \text{ , s=1,2,….} \quad \text{(A.30)}$$

With $\varphi_0 = I_k$ and $\phi_j = 0$ for $j > p$, see Lütkepohl (1991).

If deterministic or exogenous variables are present, or both, it is straightforward to extend the formula (A.28) to allow for such terms. Because the future development of deterministic variables is known by definition of the term “deterministic,” they are particularly easy to handle. They may simply be added to the stochastic part. Exogenous variables may be more difficult to deal with in some respects. They are also easy to handle if their future development is known. Otherwise they have to be predicted along with the endogenous variables. Alternatively, if the exogenous variables are under full control of a policy maker, it may be desirable to forecast the endogenous variables conditionally on a specific future path of the exogenous variables to check the future implications of their specific values.
Suppose the following reduced form model is given:

$$y_t = \mu_t + \phi_1 y_{t-1} + \cdots + \phi_p y_{t-p} + \sum_{j=0}^{q} \gamma_j Z_{t-j} + \varepsilon_t \quad . \quad \text{(A.31)}$$

As usual, μ_t summarizes the deterministic terms and Z_t represents exogenous variables. In that case, one may consider conditional expectations.

$$\begin{aligned} &E(y_{T+h} \left| y_T, y_{T-1,} \cdots Z_{T+h,} Z_{T+h-1,} \cdots \right.) \\ &= \phi_1 E(y_{T+h-1} \left| \cdots \right.) + \cdots + \phi_p E(y_{T+h-p} \left| \cdots \right.) + \mu_{T+h} + \gamma_1 Z_{T+h} + \cdots + \gamma_q Z_{T+h-q} \end{aligned} \quad \text{(A.32)}$$

The forecast errors and MSEs will be unaffected if there is no uncertainty in the future values of the exogenous variables.

A-3.2.The vector error correction model

If the variables in the VAR model have unit roots and have a common stochastic trend, it is possible there are linear combinations of them that are $I(0)$. In this case they are cointegrated. In other words, a set of $I(1)$ variables is called cointegrated if a linear combination exists that is $I(0)$. Although the model (A.22) is general enough to accommodate variables with stochastic trends, it is not the most suitable type of model if there are cointegration relations because they do not appear explicitly.

- **Model specification**

The VECM form is specified as follows.

$$\Delta y_t = \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + \prod y_{t-1} + \varepsilon_t \text{ , } \varepsilon_t \left| \Omega_{t-1} \right. \sim distr(0, H_t) \quad \text{(A.33)}$$

Here Γ and $\prod$ are coefficient matrices. $\Gamma_i = -(\phi_{i+1} + \cdots + \phi_p)$ and $\prod = -(I_k - \phi_1 - \cdots - \phi_p)$ for $i = 1, \cdots p-1$. Δ denotes the first difference operator, ε_t is a $k \times 1$ vector of error terms, following an as-yet-unspecified conditional distribution with mean zero and time-varying covariance H_t .

The VECM is obtained from the levels VAR form (A.22) by subtracting y_{t-1} from both sides and rearranging terms. Because y_t does not contain stochastic trends by our assumption that all variables can be at most $I(1)$, the term $\prod y_{t-1}$ is the only one that includes $I(1)$ variables. Hence, $\prod y_{t-1}$ must also be $I(0)$. Thus, it contains the cointegrating relations. The Γ_i are often referred to as the short-run or short-term parameters, and $\prod y_{t-1}$ is sometimes called the long-run or long-term part. The model in (A.33) will be abbreviated as VECM(p − 1). To distinguish the VECM from the VAR model, we sometimes call the latter the levels version.

Johansen and Juselius (1990) show that the coefficient matrix $\prod$ contains the essential information about the long-run relationship between variables. Suppose rank $(\prod) = r$

If $0 < r < K$, the matrix $\prod$ can be written as a product of $k \times r$ matrices α and β with rank (α) = rank (β) = r as $\prod = \alpha\beta'$. β is the vector of cointegrating parameters and α is the vector of error-correction coefficients, measuring the speed of convergence to the long-run steady state. In this case, we have r cointegrating relations and $K - r$ common stochastic trends in the model (A.33).

The model (A.33) contains several special cases. If r=0, then $\prod$ is a $k \times k$ zero matrix, implying no cointegration relationship between variables. In this case, the term $\prod y_{t-1}$ disappears in (A.33). Δy_t has a stable VAR representation. In other words, a stable VAR representation exists for the first differences of the variables rather than the levels variables. The VECM reduces to a Vector Autoregressive (VAR) model in first differences.

If r= K, i.e. $\prod$ has a full rank of $k \times k$ non-zero matrix, then different linear combinations would occur and any coefficients to y_{t-1} would be possible. In other words, all variables in y_t are $I(0)$ and the model reduces to a VAR model in levels.

Testing for the cointegrating rank

If some of the variables are $I(1)$, a VECM is the suitable modelling framework, and the cointegrating rank r has to be chosen in addition to the lag order. The rank of $\prod$ is tested by the approach proposed by Johansen (1988) and the specification in the cointegrating vector is determined by Johansen (1991). In the testing procedure of Johansen(1988), the number of significantly positive eigenvalues of the matrix $\prod$ determines the rank r of the cointegration space. This leads to two different likelihood ratio test procedures:

- Trace test: This test has the null hypothesis and the alternative hypothesis as follows:

H_0 : There are at most r positive eigenvalues

H_1: There are more than r positive eigenvalues

The test statistic is given by

$$\lambda_{trace}(r) = -T \sum_{i=r+1}^{n} \ln(1 - \hat{\lambda}_i) \tag{A.34}$$

- The maximum eigenvalue test: This test has the null hypothesis and the alternative hypothesis,

H_0 : There are exactly r positive eigenvalues

H_1: There are exactly r+1 positive eigenvalues

The test statistic is given by

$$\lambda_{\max}(r, r+1) = -T \ln(1 - \hat{\lambda}_{r+1}) \tag{A.35}$$

Where $\hat{\lambda}_i$ are the estimated eigenvalues of the $\prod$ matrix in Equation (A.33).

The series of tests starts with r = 0 and the following sequence of hypotheses may be considered:

$H_0(0)$: rank $(\prod)$ =0 versus $H_1(0)$: rank $(\prod)$ >0

$H_0(1)$: rank $(\prod)$ =1 versus $H_1(1)$: rank $(\prod)$ >1

…

$H_0(K-1)$: rank $(\prod)$ =K-1 versus $H_1(K)$: rank $(\prod)$ =K

The testing sequence terminates, and the corresponding cointegrating rank is selected when the null hypothesis cannot be rejected for the first time.

Since the test statistics do not follow standard asymptotic distributions, the critical values are generated by simulations. The critical values depend on the included deterministic terms in the VAR(p) and the specification of the deterministics in the long-run relations of the corresponding error-correction model. In general, five parameterizations of the deterministic terms in Equation (A.33) are possible:

- No deterministic trend in the data, and no intercept or trend in the cointegrating equation.
- No deterministic trend in the data, and an intercept but no trend in the cointegrating equation.
- Linear trend in the data, and an intercept but no trend in the cointegrating equation.
- Linear trend in the data, and both an intercept and a trend in the cointegrating equation.
- Quadratic trend in the data, and both an intercept and a trend in the cointegrating equation.

By using simulations, critical values for these five situations were derived by Osterwald-Lenum (1992, Table1) and Johansen (1995a, Tables 15.1 to 15.5).

Deterministic terms and exogenous variables

A VECM (*p-1*) representation with deterministic terms also exists. It has the form:

$$\Delta y_t = \mu_t + \sum_{i=1}^{p} \Gamma_i \Delta y_{t-i} + \prod y_{t-1} + \varepsilon_t \tag{A.36}$$

A rather general VECM form that includes not only deterministic terms, but also exogenous variables, is

$$\Delta y_t = \mu_t + \sum_{i=1}^{p} \Gamma_i \Delta y_{t-i} + \prod y_{t-1} + \sum_{j=1}^{q} \gamma_j Z_{r,t-j} + \varepsilon_t \tag{A.37}$$

Where μ_t is the deterministic term, the ϕ_i are $k \times k$ matrices, Z_t is the $(r \times 1)$ vector of exogenous variables, and ε_t are error terms.

The selection of deterministic terms and exogenous variables into the VECM models is determined by the criterion employed in the VAR models.

Determining the autoregressive order

Because the VECM is obtained from the levels VAR form (A.22) by subtracting y_{t-1} from both sides and rearranging terms, the model in (A.33) is abbreviated as VECM(p − 1). The lag length in the VECM is dependent on the autoregressive order of the VAR model.

- **Model estimation and checking**

If the cointegrating rank of the system under consideration is known, working with the VECM form (A.33) is convenient for imposing a corresponding restriction. Details of the ML estimation of the VECM model can be found in Johansen (1995a) and Hamilton (1994).

After the construction and estimation of the VECM model, we have to check whether a specified VECM model provides an appropriate representation of the time series. In this case, some statistical tools for residual checking will be used. A descriptive analysis of the VECM model residuals is at least partly based on the individual series. For example, plots of standardized residual series and squared residuals may be informative. In addition to the autocorrelation functions of the individual series, the cross correlations are now also informative. Additionally, a range of diagnostic tests is available for checking the model assumptions and properties formally and these tests are the same as those applied in checking the VAR model. Details of those testing procedures can be found in Lütkepohl and Krätzig (2004).

- **Forecasting a VEC model**

Forecasting vector error correction processes is similar as the prediction of the vector autoregressive process. The VECM form (A.33) is particularly convenient to use in forecasting the variable Δy_t . We will again initially ignore deterministic terms and exogenous variables. Suppose the ε_t is generated by an independent white noise process. In that case the minimum mean-squared error (MSE) forecast is the conditional expectation. For example, at forecast origin *T*, an *h*-step ahead forecast is obtained recursively as

$$\Delta y_{T+h|T} = \phi_1 \Delta y_{T+h-1|T} + \cdots + \phi_p \Delta y_{T+h-p|T} + \alpha y_{T+h-1|T} \quad (A.38)$$

Where $\Delta y_{T+i|T} = \Delta y_{T+i}$ for $j \leq 0$. The corresponding forecast error is

$$\Delta y_{T+h} - \Delta y_{T+h|T} = \varepsilon_{T+h} + \varphi_1 \varepsilon_{T+h-1} + \cdots + \varphi_{h-1} \varepsilon_{T+1} \quad (A.39)$$

If deterministic or exogenous variables are present, or both, the forecasting procedure is also similar to that applied in the VAR model. Suppose the following reduced form model is given:

$$\Delta y_t = \mu_t + \phi_1 \Delta y_{t-1} + \cdots + \phi_p \Delta y_{t-p} + \alpha y_{t-1} + \sum_{i=0}^{q} \gamma_j Z_{r,t-j} + \varepsilon_t \quad (A.40)$$

As usual, μ_t summarizes the deterministic terms and Z_t represents exogenous variables. In that case, one may consider conditional expectations.

$$\begin{aligned} &E(\Delta y_{T+h} \left| \Delta y_T, \Delta y_{T-1}, \cdots, y_{T-1}, y_{T-2}, \cdots, Z_{T+h}, Z_{T+h-1}, \cdots \right.) \\ &= \phi_1 E(\Delta y_{T+h-1} | \cdots) + \cdots + \phi_p E(\Delta y_{T+h-p} | \cdots) + \alpha E(y_{T+h-1} | \cdots) + \mu_{T+h} + \gamma_1 Z_{T+h} + \cdots + \gamma_q Z_{T+h-q} \end{aligned} \quad (A.41)$$

The forecast errors and MSEs will be unaffected if there is no uncertainty in the future values of the exogenous variables.

A-4. Conditional heteroskedasticity

All models discussed so far use the conditional expectation to describe the mean development of one or more time series. The optimal forecast, in the sense that the variance of the forecast errors will be minimised, is given by the conditional mean of the underlying model. Here, it is assumed that the residuals are not only uncorrelated but also homoskedastic, i.e. the unexplained fluctuations have no dependencies in the second moments.

However, Researchers in early work have already found that financial market data display the volatility clusters, for instance, Mandelbrot (1963) and Fama(1965). Periods of higher and smaller price variations alternate and empirical volatilities tend to cluster. The latter property is easily found in the empirical autocorrelation function of squared returns. Thus, although price processes are hardly predictable, the variance of the forecast error is time dependent and can be estimated by means of observed past variations.

The phenomenon of time-varying volatility is well known and has generated a vast body of econometric literature following the seminal contributions by Engle (1982), Bollerslev (1986), and Taylor (1986) introducing the (generalised) autoregressive conditionally heteroskedastic ((G)ARCH) process and the stochastic volatility model, respectively.

This section will concentrate on the class of GARCH models. More detailed surveys of GARCH models are offered by Bollerslev, Engle & Nelson (1994), Bollerslev, Chou & Kroner (1992), Pagan (1996) and Palm (1996) among others.

A-4.1. The specification of GARCH Models

Since its introduction, the univariate GARCH model has been applied in countless empirical studies. The GARCH(1,1) model has turned out to be particularly useful for describing a wide variety of financial market data, see Bollerslev et al. (1994). Therefore, this part focuses mainly on this parsimonious specification of conditional heteroskedasticity.

A representation of the GARCH *(p,q)* model (Bollerslev (1986)) can be seen as follows.

$$\begin{aligned} &\varepsilon_t = \sqrt{h_t} z_t, \, z_t \sim iid(0,1) \\ &h_t = \omega + \alpha_1 \varepsilon_{t-1} + \cdots + \alpha_p \varepsilon_{t-p} + \beta_1 h_{t-1} + \cdots + \beta_q h_{t-q} \end{aligned} \quad (A.42)$$

Note that if q=0, the GARCH(p,q) becomes the ARCH(p) process, see Engel(1982). The sufficient conditions for the conditional variances h_t to be positive is, $\omega > 0$ and $\alpha_i, \beta_j \geq 0$, $i = 1, \cdots p$, $j = 1, \cdots q$

Unconditional moments

The unconditional distribution of a GARCH process is leptokurtic. In comparison with the normal distribution, the unconditional distribution of ε_t shows higher mass around the zero mean and in its tails. The latter result becomes evident from investigating the unconditional moments of the GARCH process. To facilitate the presentation, consider the GARCH(1,1) model. Then, applying the law of iterated expectations, we find that the unconditional variance is

$$\begin{aligned} E(\varepsilon_t^2) &= E(E(\varepsilon_t^2 | \Omega_{t-1})) \\ &= \omega + \alpha_1 E(\varepsilon_{t-1}^2) + \beta_1 E(E(\varepsilon_{t-1}^2 | \Omega_{t-2})) \\ &= (1 - \alpha_1 - \beta_1)^{-1} \omega \end{aligned} \qquad \text{(A.43)}$$

Moreover, under conditional normality the fourth-order moment of the GARCH(1,1) process is,

$$E(\varepsilon_t^4) = \frac{3\omega^2(1 + \alpha_1 + \beta_1)}{(1 - \alpha_1 - \beta_1)(1 - \beta_1^2 - 2\alpha_1\beta_1 - 3\alpha_1^2)} \qquad \text{(A.44)}$$

Note that $E(\varepsilon_t^4)$ only exists if

$$\beta_1^2 + 2\alpha_1\beta_1 + 3\alpha_1^2 < 1 \qquad \text{(A.45)}$$

From the results in (A.43) and (A.44), the kurtosis of the GARCH(1,1) under the conditional normality is derived as,

$$\kappa = \frac{E(\varepsilon_t^4)}{(E(\varepsilon_t^2))^2} = \frac{3(1 - \alpha_1 - \beta_1)(1 + \alpha_1 + \beta_1)}{(1 - \beta_1^2 - 2\alpha_1\beta_1 - 3\alpha_1^2)} \qquad \text{(A.46)}$$

Under the parameter restrictions made for positivity of conditional variances and existence of the fourth-order moment, it holds that $\kappa > 3$, indicating leptokurtosis of ε_t . Note that it is the ARCH parameter α_1 that governs volatility clustering and leptokurtosis. In case $\alpha_1 = 0$, the GARCH(1,1) model is not identified ($\kappa = 3$), and for $\beta_1 = 0$, excess kurtosis increases with α_1.

A-4.2. The estimation of GARCH process

The estimation of GARCH models is explained in detail in Lütkepohl and Krätzig (2004). To discuss maximum likelihood (ML) estimation of GARCH models, we assume for the moment that a finite stretch of observations ε_t are available. Specifying the joint density of $\varepsilon_1, \cdots \varepsilon_T$ makes use of its representation as the product of some conditional and the corresponding marginal density. Let Ω_{T-1} denote the sequence of random variables $\varepsilon_0, \varepsilon_1, \cdots \varepsilon_T$. On the assumption that ε_0 is constant or is drawn from a known distribution, the joint distribution of a finite stretch of observations from a GARCH process is

$$\begin{aligned} f(\varepsilon_{1,} \cdots \varepsilon_T) &= f(\varepsilon_T | \Omega_{T-1}) \cdot f(\Omega_{T-1}) \\ &= f(\varepsilon_T | \Omega_{T-1}) \cdot f(\varepsilon_{T-1} | \Omega_{T-2}) \cdots f(\varepsilon_1 | \Omega_0) f(\Omega_0) \end{aligned} \qquad \text{(A.47)}$$

The conditional distributions in Equation (A.47) are available from the definition of the GARCH(q, p) process in Equations (A.42). Then, under the normality assumption, the log-likelihood function is, conditional on some initialization σ_0 , given as,

$$\begin{aligned} l(\theta | \varepsilon_{1,} \cdots \varepsilon_T) &= \sum_{t=1}^{T} l_t \\ &= \sum_{t=1}^{T} l_t \left(-\frac{1}{2}\log(2\pi) - \frac{1}{2}\log\sigma_t^2 - \frac{1}{2}\frac{\varepsilon_t^2}{\sigma_t^2}\right) \end{aligned} \qquad \text{(A.48)}$$

In some applications, it is more appropriate to assume that t follows a heavy tailed distribution such as a standardized Student-*t* distribution. Suppose a random variable ε_t is *t* distributed with *v* degrees of freedom, mean zero, and variance σ^2 if it has the following density:

$$f(\varepsilon_t|v) = \frac{\Gamma((v+1)/2)}{\Gamma(v/2)\sqrt{\pi(v-2)}} \cdot \sigma_t^{-1} \cdot (1+\frac{\varepsilon_t^2}{(v-2)\sigma_t^2})^{-\frac{v+1}{2}} \quad \text{(A.49)}$$

In Equation (A.49), $\Gamma(\cdot)$ denotes the Gamma function, Recall that for $v \to \infty$, the density in (A.49) coincides with the Gaussian density. The contribution of a single observation to the log-likelihood function is,

$$\begin{aligned} l(\theta, v) &= \log(f(\varepsilon_t)|\Omega_{t-1}) \\ &= \log(\Gamma((v+1)/2)) - \log(\Gamma(v/2)\sqrt{\pi(v-2)\sigma_t^2}) - \frac{v+1}{2}\log(1+\frac{\varepsilon_t^2}{(v-2)\sigma_t^2}) \end{aligned} \quad \text{(A.50)}$$

Compared with the common case with independent random variables, the ML estimator $\hat{\theta}$ cannot be obtained analytically but requires iterative optimization routines. A particular optimization routine that is often used to estimate the model (A.42) is the BHHH algorithm named after Berndt, Hall, Hall &Hausman (1974). Details can be seen in Bollerslev (1986), Fiorentini, Calzolari & Panattoni (1996) and Lütkepohl and Krätzig (2004)

A-4.3. Extensions

As provided in the model (A.42), the GARCH process is characterized by a symmetric response of current volatility to positive and negative lagged errors ε_{t-1}. Positive and negative innovations that are equal in absolute value imply the same impact on the conditional variance σ_t^2. Since ε_t is uncorrelated with its history, it could be interpreted conveniently as a measure of news entering a specified market on time t. In empirical work, it is known that sometimes the volatility of variables of interest is much more affected by negative compared with positive news, see Black (1976).The described asymmetry in response to market news has become popular as the so-called leverage effect, which is obviously not captured by the basic GARCH process discussed so far.

To allow for different impacts of lagged positive and negative innovations, Nelson (1991) has proposed the exponential GARCH model (EGARCH). Under conditional normality the EGARCH(1,1) model reads as follows:

$$\begin{aligned} &\varepsilon_t = \sqrt{h_t} z_t,\ z_t \sim iid(0,1) \\ &\log(h_t) = \omega + \varphi z_{t-1} + \alpha(|z_{t-1}| - E|z_{t-1}|) + \beta \log(h_{t-1}) \end{aligned} \quad \text{(A.51)}$$

Where the persistence of variance is measured by magnitude of β: the closer the magnitude approaches unity, the greater the persistence of shocks to volatility. The positivity and negativity of unanticipated excess returns determines future variance, which is measured by φ and α. The φ is a sign effect. If $\varphi = 0$, this means the non-existence of asymmetric volatility; if $\varphi > 0$ and statistically significant, this implies the volatility of positive innovations is larger than that of the same magnitude of negative innovations; if $\varphi < 0$ and statistically significant, this means the volatility of return shocks is asymmetric and the volatility of negative innovations is larger than that of the same magnitude of positive innovations. The negative φ represents the presence of leverage effect. The α represents a magnitude effect. For $\alpha > 0$, the innovation in $\log h_t$ is then positive (negative) when the magnitude of z_t is larger (smaller) than its expected value.

A-4.4. Specification testing

Apart from a visual inspection of the autocorrelation function of a squared (estimated) GARCH process, formal tests of homoskedasticity against the presence of ARCH-type variances are in widespread use.

Based on the Lagrange multiplier (LM) principle, an asymptotically equivalent test, the familiar ARCH–LM test, is given in Engle (1982). Engle & Ng (1993) proposed LM tests of the symmetric GARCH model against volatility models allowing asymmetry, so-called size effects, or both.

A-5. Other methods

Not only statistical evaluation of economic variables and relations between them are analyzed in the freight market, the second-hand ship market and the newbuilding ship market of dry bulk shipping, but also the economic and the technical performance of ships are studied. Speed and fuel consumption are crucial elements of the technical performance of specific ships. In order to evaluate impacts of these technical issues into ship's economic performance, ship resistance and power prediction should be determined. In our analysis, we use the power prediction method created by Holtrop and Mennen(1979). The power installed is determined by the hull and propeller performance. The lightweight of ships, therefore, should be estimated.

- **The lightweight estimation method**

The weight of hull is the sum of structural steel weight, outfitting weight, machinery weight and the others.

$$W_{sm} = W_s + W_o + W_d + W_r \qquad (A.52)$$

Where W_s means the corrected weight of structural steel, W_o is the outfitting weight, W_d denotes machinery weight and W_r is the remaining weight of the engine room equipment.

Structural steel is estimated as:

$$W_{si} = K \times E^{1.36} \qquad (A.53)$$

Where E is the Lloyd's equipment number; K is ship type dependent and it is around 0.031±0.002 for bulk carriers.

The Lloyd's equipment number E is calculated as,

$$E = L \times (B+T) + 0.85 \times L\,(D-T) \qquad (A.54)$$

Where L means the length on the waterline of the vessel approached by the average of the length overall and the length between perpendiculars. B denotes the breadth of the vessel, T is the draft and D is the depth of a vessel.

W_{si} is evaluated at a standard block coefficient of 0.7 at $T = 0.8 \times D$. Eventually, Ws is corrected for the real block coefficient. The accommodation is neglected.

$$W_s = W_{si}\,(1+0.05 \times (C_b-0.7)) \qquad (A.55)$$

Outfit weight is a function of L_{pp} and ($L_{pp} \times B$). This approach is excluding cranes.

$$W_o = wo\,(L_{pp} \times B) = (0.31975 - 0.00058 \times L_{pp}) \times (L_{pp} \times B) \qquad (A.56)$$

Where L_{pp} is the length between perpendiculars

Machinery weight is a function of the torque and as such a function of the ratio MCR/rpm, with MCR as the maximum continuous rating in kW and rpm. Since the area of investigation is on the bigger size of vessels the rpm has been set on 90, indicating two stroke engines.

$$W_d = 12(MCR/rpm)^{0.84} \qquad (A.57)$$

Where rpm means the number of revolutions per minute

The remaining weight of the engine room equipment is determined by the function,

$$W_r = K \times MCR^{0.7} \quad (A.58)$$

Where K = 0.69 for bulk carriers.

The weight of a vessel according a statistical approach with the main dimensions of the vessel as parameters enables us to set a benchmark for each vessel in the database and calculate the percentage more or less weight.

- **The power estimation method**

The calculation method developed by Holtrop and Mennen(1979) is based on the tests done at the ship towing basin MARIN in Wageningen. The method as such is a polynomial approach of all the test results from Marin. The impact of the main dimensions and the hull shape defining parameters on the effective power P_E has been estimated by means of a statistical evaluation. The vessels used have already been optimized. This means that it is possible to find vessels which were not tested in a towing basin with substantially higher power requirements. The accuracy of the system is approximately 10% as a resistance predictor for a specific vessel. Detailed optimization after the conceptual design stage is always advisable and can lead easily to a 10% less, and with the additional investment even a 20% less in the fuel consumption.

The following parameters with minor influence on the power prediction are estimated:

C_m	set on 0.995
C_p	the prismatic coefficient calculated by means of C_b (known) and Cm
C_{wp}	estimated based on the block coefficient C_b and the formula according to Henschke
I_e	half entrance angle of the vessel. It's defined as a function of C_p and L_{cb}.
I_r	Length of the run, the length of the non-parallel aft body
L_{cb}	set on 4% of the length forward of half ship, believed to be the right position for these types of vessels and speeds.
Sea margin	adjustable but set at 15%, an allowance for operational conditions for the installed power
Efficiency	the overall propulsion efficiency is calculated for one vessel and set on 0.65
Aft transom	the impact of a submerged aft flat transom is neglected
Bulb	the impact of a bulb to reduce the winemaking resistance is neglected

This calculation is executed three times in the model. At first to determine the installed power of the design by using a maximum design speed for the bulk carrier of 14.5 knots, based on a database of 300 bulk carriers from Handymax till Capesize. Secondly to determine the fuel consumption in the laden condition and thirdly in the ballast condition both optimized towards the lowest costs per ton-mile. The first calculation determines the investment for the main engine system and the last two calculations determine the heavy fuel oil consumption.

Besides the heavy fuel oil consumption there is also a marine diesel oil consumption which takes care of the electric power generation. This one is estimated as a function of the size of the vessel.

Appendix B: Route descriptions of Baltic Panamax Index before Oct 2002

Table Ⅰ: Route descriptions of Baltic Panamax Index before Oct 2002

Routes	Route Description	Cargo	Vessel Size(dwt)	Weightings in BPI
1	1–2 safe berths/anchorages US Gulf (Mississippi River not above Baton Rouge) to ARA (Antwerp, Rotterdam, Amsterdam)	Light Grain	55,000	10%
1A	Transatlantic (including East Coast of South America) round of 45–60 days on the basis of delivery and redelivery Skaw Passero range.	T/C	70,000	20%
2	1–2 safe berths/anchorages US Gulf (Mississippi River not above Baton Rouge) / 1 no combo port to South Japan	HSS	54,000	12.5%
2A	Basis delivery Skaw Passero range, for a trip via Gulf to the Far East, redelivery Taiwan–Japan range, duration 50–60 days	T/C	70,000	12.5%
3	1 port US North Pacific / 1 no combo port to South Japan	HSS	54,000	10%
3A	Transpacific round of 35–50 days either via Australia or Pacific (but not including short rounds such as Vostochy/Japan), delivery and redelivery Japan/South Korea range.	T/C	70,000	20%
4	Delivery Japan/South Korea range for a trip via US West Coast–British Columbia range, redelivery Skaw range, duration 50–60 days	T/C	70,000	15%

Source: Baltic Exchange

Notes: From the formulation of the FFA market on February 1st 1992 until November 1st 1999, the eleven Panamax and Capesize voyage and time-charter routes of the Baltic Freight Index (BFI) served as the underlying assets of the FFA trades, in the dry-bulk sector of the shipping industry. After the latter date, with the exclusion of the Capesize routes and with the renamed index as Baltic Panamax Index (BPI), the underlying assets of the FFA contracts are Panamax routes. The composition of the BPI, as it stands till Oct 2002, is presented in the table. Since Nov 2002, the constituent routes of the BPI have been updated and/or revised for several times. The latest route descriptions in Dec 2010 can be found in Page 112.

Appendix C : Wald test statistic on restrictions

$$e1' = \theta\delta Ae2'(I-\delta A)^{-1}(I-\delta^{n-1}A^{n-1}) - \theta\delta^{n}e2'(I-A)^{-1}(I-A^{n-1})$$

This formula states the cross equation restrictions on the VAR model. These restrictions can be tested formally using a non-linear Wald test statistic. Define a function *f* as:

$$f = e1' - \theta\delta Ae2'(I-\delta A)^{-1}(I-\delta^{n-1}A^{n-1}) - \theta\delta^{n}e2'(I-A)^{-1}(I-A^{n-1})$$

Denote the vector of estimated coefficients of the VAR system by γ. Then the Wald test statistic for nonlinear restrictions can be expressed as:

$$W = f' \times [\frac{\partial f}{\partial \gamma'}\hat{\Omega}\frac{\partial f}{\partial \gamma}]^{-1} \times f$$

Where $\hat{\Omega}$ is the estimated covariance matrix of the estimated coefficients. The partial derivatives are evaluated using a numerical approximation procedure. Under the null, this test statistic has a $\chi^2(r)$ distribution with degrees of freedom equal to the number of restrictions *r*.

Curriculum Vitae

Shun Chen was born in Changzhou, China, on 16th Feb 1979. She obtained a bachelor and a master degree in maritime economics at Shanghai Maritime University in 2002 and in 2004, respectively. After her graduation in 2004, she was employed as an assistant in teaching at the department of International Shipping in Shanghai Maritime University. Since 2005, she has worked as a university lecturer and teaches on topics in maritime business, shipping management and logistics. Furthermore, she has taken part in a number of research projects on maritime and port related topics, and has written a number of papers that were published in various journals.

In October 2007, she started her PhD research in the department of Maritime Transport and Technology at the Faculty of 3ME at Delft University of Technology, the Netherlands, jointly supervised by professors at University of Antwerp. Her research project was aimed at modelling price behavior and making the prediction of prices in the dry bulk freight market, the new-building ship market and the second-hand ship market.

Apart from her research experience at universities, she also works as a market researcher focusing on the dry bulk shipping market for Chinica Shipbrokers Ltd. in Shanghai, China since 2004.

Publications

Shun Chen, Hilde Meersman and Eddy van de Voorde (2010). Dynamic interrelationships in returns and volatilities between Capesize and Panamax markets. *Journal of Maritime Economics &Logistics*, 12: 65-90.

Shun Chen, Koos Frouws and Eddy van de Voorde (2010). Technical changes and impacts on economic performance of dry bulk vessels. *Journal of Maritime Policy and Management*, 37(3): 1-23.

Shun Chen, Koos Frouws and Eddy van de Voorde (2011). Simulation-based optimization of ship design for dry bulk vessels. *Journal of Maritime Economics and Logistics*,13:190-212.

Shun Chen, Koos Frouws and Eddy van de Voorde(2009). Impacts of technical changes on the economic performance of dry bulk vessels. *The WCTR-Special Interest Group 2*, Antwerp, Belgium, 7-8 May.

Shun Chen, Hilde Meersman and Eddy van de Voorde (2009). Dynamic interrelationships in returns and volatilities between Capesize and Panamax markets. *The 19th International Association of Maritime Economists (IAME) Conference*, Copenhagen, Denmark, 24-26 June.

Shun Chen, Koos Frouws and Eddy van de Voorde (2010). Operation-based optimization of ship design for dry bulk vessels. *The proceedings of the 12th World Conference on Transport Research (WCTR)*, Lisbon, Portugal, 11-15, July.