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An Empirical Analysis of the Price Discovery Function in Tanker Forward Freight Agreement Market

by

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Abstract

Tanker freight market is renowned for exposing freight risks to market participants due to the great freight volatility. Forward freight agreements (FFA), as principal-to-principal derivatives contracts, are traded for hedging freight risks as well as speculation. It is deemed that in tanker freight market, there is lead-lag relationship between spot price and forward price. Moreover, the price discovery function of the forward price plays an essential role in tanker freight market to guide future spot price. Hence, researching on these subjects has vital economic and practical significance. This paper employs vector autoregressive model (VAR) to analyze the lead-lag relationship between spot price and forward price in tanker freight market as well as the effects of the price discovery function of FFA in-depth. The results of this paper would provide some references for market participants to manage risks and make better strategies.

Keywords: Tanker freight market; Forward freight agreement; Vector autoregressive model; Price discovery function

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List of Abbreviations

COA	Contract of Affreightment
FFA	Forward Freight Agreement
COSCO	China Ocean Shipping Company
VAR	Vector Autoregressive
ARCH	Autoregressive conditional heteroscedasticity
VLCC	Very Large Crude Carrier
ULCC	Ultra Large Crude Carrier
BIFFEX	Baltic International Freight Futures Exchange
BDTI	Baltic Dirty Tanker Index
IMO	International Maritime Organization
OTC	Over the Counter
WS	Worldscale
ADF	Augmented Dickey-Fuller
AIC	Akaike Information Criterion
SC	Schwarz Criterion
BITR	Baltic International Tanker Routes
VECM	Vector Error Correction Model
IRF	Impulse Response Function
S.D.	Standard Deviation

Chapter 1 Introduction

1.1 Research Background

Shipping market is always a place full of risks due to its characteristics. The demand for shipping is derived from international trade. Therefore, shipping industry is undoubtedly subject to the global and regional economic development as well as economic cycles. Additionally, political and natural conditions should not be overlooked either. To sum up, shipping market is volatile.

From a conventional point of view, in order to circumvent market risks, shipping enterprises generally split their fleet to operate or sign contracts of affreightment (COA). Such measures are still prevailing amongst ship owner currently. However, these measures are considered to be inflexible and unreliable, which cannot fulfill the demands for risk management. Under such circumstances, Forward Freight Agreement (FFA), "*conceived by Clarksons in 1991 for dry cargoes*" (Dinwoodie & Morris 2010), "*was devised to cushion against volatile prices and lock-in future freight rates and secure certain freight revenue*" (Dinwoodie & Morris 2010). The appearance of FFA has brought great vigor to the shipping derivatives market.

The trading volume of FFA has been rising year by year and reached 56 billion U.S. dollars of market value in 2006 (Askci 2008). Notwithstanding encountering slumps in 2012, the status of FFA in shipping derivatives market cannot be swayed. However, it is believed that the trading of FFA is not transacted all by shipping operators. Since 2004, financial magnates led by Morgan Stanley have flooded into FFA market for speculation (Zhang 2007). At the same time, many shipping enterprises started to make money with arbitrage trading by controlling spot market. COSCO, renowned as the greatest Chinese shipping giant, even attempted to make arbitrage by trading considerable FFA contracts in 2008 (Zeng 2008). However this behavior only brought huge losses for it. In contrast, due to eruption of the financial crisis at that time, the TMT Group became one of the biggest the winners by shorting FFA contracts (Zeng 2008). Apparently, speculations have been one of the driving forces to facilitate the growth of FFA trading.

Tanker freight market is known as not a perfectly competitive market. Thus, the promotion of tanker FFA is relatively sluggish. However, considering the huge average capacity of vessel and the high value of goods, the market value of tanker FFA has been rising in recent years. In 2007, the amount of transactions of tanker FFA was 13351, and the corresponding volume of oil was 0.374 billion tons (ShippingOnline 2007).

The volatility of freight rates in tanker freight market has brought many uncertainties as well as new opportunities. How to understand tanker FFA and how to use this to hedge the risks incurred by volatility of freight rates has been a key issue for the participants in this market to survive and maximum their profits. Hence, a good understanding of the relationship between spot freight rates and forward freight rates is becoming increasingly significant.

1.2 Problem Statement

As Kavussanos and Nomikos (2003) explained: "*Price discovery is the process of revealing information about future spot prices through the futures market* " (Kavussanos & Nomikos 2003). Due to the great volatility of freight rates in tanker freight market, being well acquainted with the price discovery function of tanker FFA is significant for the participants in this market to control spot price risks. Nowadays, there are totally 15 dirty tanker routes and 6 clean tanker routes transacting FFA contracts. Along with the rising of FFA trading volume, an increasing number of speculations have given rise to more sharp fluctuation and illusively high freight rates. Therefore, a good understanding of price discovery process of tanker FFA in tanker freight market has more practical significance for shipping operators.

However, since the empirical data in forward market is not easy to be collected, there are not too many relevant researches being conducted (Kavussanos & Visvikis 2004). In this paper, the author aims to make an empirical analysis of the price discovery function in tanker FFA market on the basis of vector autoregressive model. By that, the author will explore the relationship between spot price and forward price in tanker freight market.

1.3 Research Objectives

With the help of vector autoregressive model, the author focuses on whether there is any relationship between spot prices and forward prices in tanker freight market. If so, how these interactions work in both short term and long term. What is the underlying economic significance behind this relationship? The author aims to provide a reference for the tanker shipping operators to perceive the risks, learn how to control risks with FFA and develop more robust operating strategies on the basis of these research results.

1.4 Research Questions

The main research question for this thesis is the price discovery function in tanker FFA market. In order to analyze this question systematically, the author set these following sub-questions underlying a certain logic sequence.

1. What is the main status of tanker freight market?

2. What is the main status of tanker forward market and how does the forward price function in this market?

3. Whether there is lead-lag relationship between spot price and forward price in tanker freight market? If so, how does this relationship function?

4. Are the impacts between spot price and forward price unidirectional or bidirectional? If they are bidirectional, the impacts on which direction is stronger?

5. Whether there exists price discovery function in forward market to reveal information about future spot prices? What is the extent of it?

1.5 Research Methodology

After reviewing relevant literatures in this field, the author determined to use vector autoregressive model as the main method to test the relationship between spot price and forward price in tanker freight market. Considering the trading volume of FFA, the author selected TD3 and TD5 routes as the targets of the empirical analysis. Corresponding data were also collected.

More explicitly, in order to make a preliminary analysis of the relationship between spot price and forward price, the author will first calculate the coefficient of correlation of two series comprised by these two prices.

Secondly, as the foundation of vector autoregressive model, Augmented Dickey-Fuller test, Johansen test, determination of lag order, error correction model and Granger causality test will be carried out. During these processes, further perceptions of the relationship between these two types of prices will be obtained.

Last but not least, the author will construct vector autoregressive model and then apply techniques of impulse response function and variance decomposition to make in-depth analyses and finally answer the research questions set by the author.

1.6 Research Structure

The thesis will be structured as seven chapters. The main contents of these chapters are introduces below:

Chapter 1: the main research background and the thread of this thesis were introduced in this chapter. The main research questions were divided into several sub-questions herein.

Chapter 2: relevant literatures were reviewed in this chapter to help the author understanding the relevant conceptions and methods, and then find more ideas on both the qualitative and quantitative analyses.

Chapter 3: a qualitative analysis of tanker freight market was carried out so as to lay a good foundation for the further analysis. At the same time, this analysis also provides theoretical support for answering research questions.

Chapter 4: a qualitative analysis of tanker forward market and FFA. In order to make an analysis on forward prices, the inherent characteristics of the forward market and the mechanism of the operation of FFA are necessary.

Chapter 5: research methodology was introduced specifically herein. The principals of these methods were explained as well as the main reasons for using these methods, the preconditions of them and their effects.

Chapter 6: as the core chapter of this thesis, the empirical analysis with vector autoregressive model and relevant methods was carried out herein. By analyzing the results, the aforementioned sub-questions were answered and some economic significance and inspirations were put forward.

Chapter 7: conclusions about the overall thesis were drawn in this chapter. Furthermore, a number of suggestions regarding the research as well as some limitations of the thesis were proposed.

Chapter 2 Literature Review

2.1 Introduction

This thesis aims to systematically analyze the price discovery function in tanker forward freight agreement (FFA) market from both the qualitative and quantitative perspectives. In order to accomplish a scrupulous and creative thesis, the author reviews literature from various aspects which are highly correlated with the thesis's main statement. Pros and cons of these literatures are estimated such that helpful opinions and methodologies are used for reference.

Figure 2-1 below illustrates the outline of the author's literature review, which is also the tread for conducting this research.

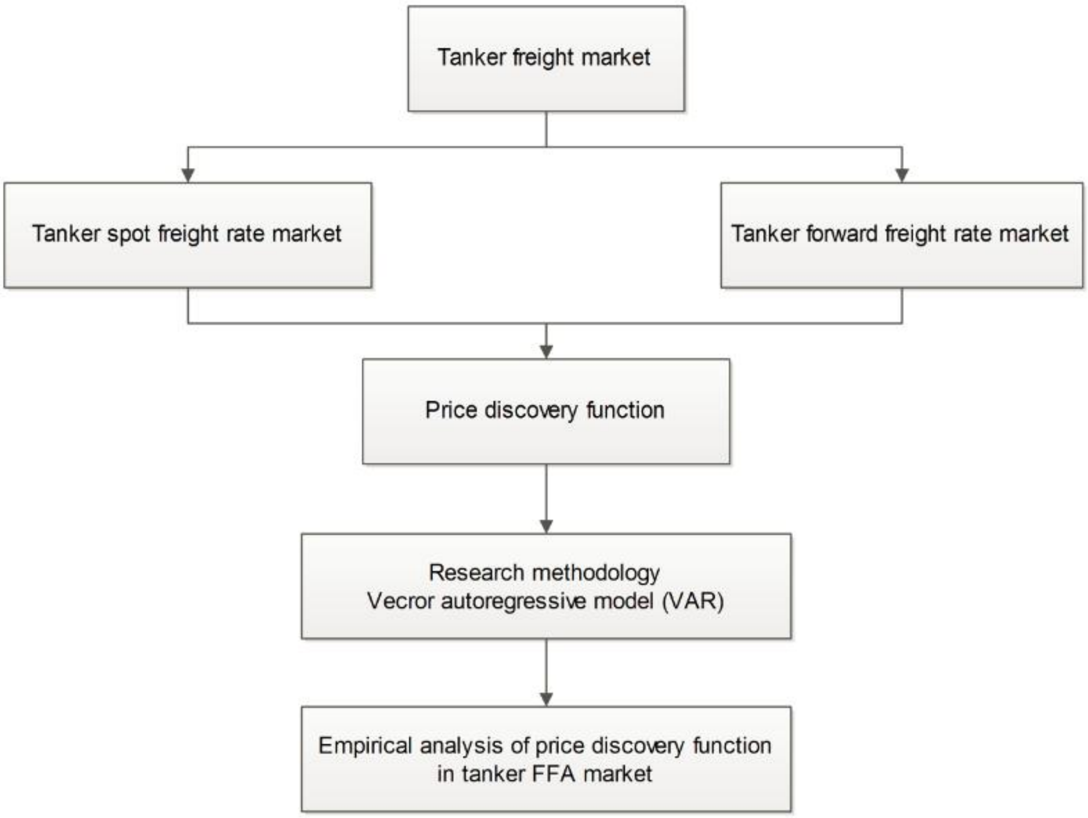

Figure 2-1 Outline of literature review
Source: compiled by the author

Section 2.2 firstly review literatures related to tanker freight market, which is the basis market of this thesis. Afterwards, the author focuses on tanker spot freight rate market and forward freight market respectively in section 2.3. In particular, literatures about forward freight agreement are also review herein. Subsequently, the author studies researches on price discovery function and relevant articles in section 2.4. Finally, as the core of the thesis, the investigation on research methodology is placed in section 2.5. Pros and cons of various econometrical models are studied and compared herein.

2.2 Tanker Freight Market

Lun *et al* (2013) demonstrated the configuration of tanker shipping industry in their book *Oil Transport Management:*
"The tanker shipping industry comprises four different but closely associated markets. Sea transport services are dealt in the freight market, new ships are ordered and built in the new building market, used ships are traded in the sale and purchase market, and old or obsolete ships are scrapped in the demolition market" (Lun et al. 2013).

They believed that "*the supply of tanker shipping operates under perfect competition is characterized by several conditions"* (Lun et al. 2013). First off, a number of ship owners provide identical services. Secondly, information about tanker freight rate is transparent. It is unavailable for shipping service suppliers to manipulate the price. Moreover, entry barriers are not present in the tanker shipping industry, whereas shipping firms need huge capital investment to acquire ships; otherwise they withdraw from the market by selling assets in second-hand vessel market.

Lun *et al* (2013) also argued that in tanker freight market, the suppliers – tanker fleets – sell shipping services as products. Hence, "*tanker freight rate is the value that shippers, who demand for shipping services, are willing to pay*" (Lun et al. 2013).

2.3 Tanker Spot Freight Rate Market and Forward Freight Rate Market

Koopmans (1939) first analyzed the volatility of freight rate market. Since then, volatility of freight rate market and the modelling research of spot freight rate market turned to be the research focuses of maritime economics (Koopmans 1939). With the help of empirical analysis, Zannetos (1966) improved the short-term supply curves in freight rate market proposed by Koopmans (Zannetos 1966) .

Both short-term and long-term tanker markets were simulated with a tanker model by (Hawdon 1978). Afterwards, Norman and Wergeland (1981) established an econometrical model for VLCCs in order to separate over-200-thousand-ton tankers from the overall tanker market; therefore econometrical models can guide tanker shipping practices more specifically (Norman & Wergeland 1981).

Kavussanos, a prestigious maritime economist, made in-depth researches in tanker freight rate market. Kavussanos (1996) used autoregressive conditional heteroscedasticity (ARCH) to study the characteristics of volatility of freight rates for various ship types as well as expounding the reasons of the severe volatilities and the impacts for risks (Kavussanos 1996). Kavussanos (1998) further analyzed the risks for different ship types in tanker freight market and finally concluded that the risk for VLCC's freight rate was higher than small tankers (Kavussanos 1998).

Kavussanos (1999) investigated the unbiasedness hypothesis of futures prices in the freight futures market and concluded that "*futures prices one and two months before maturity are unbiased forecasts of the realized spot prices, whereas a bias exists in the three-months futures prices…Despite the existence of a bias in the three months prices, futures prices for all maturities are found to provide forecasts of the realized spot prices that are superior to forecasts generated from error correction, ARIMA, exponential smoothing, and random walk models. Hence it appears that users of the*

BIFFEX market receive accurate signals from the futures prices (regarding the future course of cash prices) and can use the information generated by these prices to guide their physical market decisions" (Kavussanos 1999).

Kavussanos and Alizadeh (2002) investigated the seasonality of freight rates for 4 types of tankers (VLCC/ Suezmax/ Aframax/ Handysize). Through this research, he believed that there existed seasonality in tanker freight rate market regardless of ship types (Kavussanos & Alizadeh 2002).

Kavussanos also did massive researches on forward freight agreement (FFA). The scopes of his researches include the price discovery mechanism of FFA, hedging effects, analysis of information flow and yields in spot freight rate and forward freight rate market, and the effects of FFA on the volatility in spot freight rate market. He also proposed that 3 reasons are considered to attract so many scholars to conduct researches, which are presented as below:

1. Researches on FFA are significant for the efficiency of tanker market and decision making for shipping operators;
2. Derivative market plays a vital role for price discovery function in freight market;
3. If there are volatility spillovers from one market to another, then the volatility can be used to cover risks. Therefore, FFA can be treated as a price discovery tool (Kavussanos & Visvikis 2004).

Researches on the volatility in spot freight market and FFA market play an essential role because forward freight rate market currently is an important part of derivatives market in marine industry. Kavussanos (2004) used GJR-GARCH model to analyze the relationship between dry bulk FFA and volatility of spot freight rate. With an empirical analysis, the research was carried out with the FFA prices in two panamax Atlantic routes (1 and 1A) and two panamax Pacific routes (2 and 2A). The results indicated that routes 1A and 2A reflected directly to the introduction of FFA, whereas the other two routes did not have significant reflects (Kavussanos, Visvikis & Menachof 2004).

2.4 Price Discovery Function

Schwartz and Francioni (2004) defined price discovery process as "*the process of determining the price of an asset in the marketplace through the interactions of buyers and sellers*" (Schwartz & Francioni 2004) in their book *Equity Markets in Action: The Fundamentals of Liquidity, Market Structure & Trading.*

Kavussanos and Nomikos (2003) investigated the causal relationship between spot freight rate and forward freight rate in the freight futures market. They drew a conclusion as: "*futures prices tend to discover new information more rapidly than spot prices. Revisions in the composition of the underlying index to make it more homogeneous have strengthened the price discovery role of futures price*" (Kavussanos & Nomikos 2003).

2.5 Research Methodology

Since considerable financial time series are non-stationary, using conventional analysis methods lacks rationality. In order to solve this problem, Engle, Granger, Johansen and Juselius put forward cointegration theory. This provided a new way to study the equilibrium relationship between disequilibrium economical variables. Nowadays, this method is widely used in analyzing dynamic relationship between spot freight rate and forward freight rate. Its advantage is that, in most regression analysis, spot freight rate and forward freight rate are assumed to reflect identically to new information in the market in time. Furthermore, these two freights are allowed to deviate from equilibrium in a short period. As for long period, there is a long-term equilibrium relationship between these two freight rates.

Kavussanos and Visvikis (2004) collected empirical data of the over-the-counter traded FFA to analyze the lead – lag relationship in both returns and volatilities between spot and FFA price series in the panamax voyage routes 1 and 2 and time-charter routes 1A and 2A. The main research result is that: "*despite the non-storable nature of the market, FFA prices contribute to the discovery of new information in the spot market, and can be equally important as sources of information as spot prices are in commodity and financial markets. Furthermore, the results of the bi-directional lead – lag relationship in the means are in accordance with the results in most futures markets. In addition, results show that OTC contracts discover information faster compared to spot markets, a result which may be attributed to the higher transaction costs in spot freight markets compared to the FFA markets*" (Kavussanos & Visvikis 2004).

Zivot and Wang (2006) introduced vector regressive model in their article *Vector Autoregressive Models for Multivariate Time Series* as below:
"*The VAR model has proven to be especially useful for describing the dynamic behaviour of economic and financial time series and for forecasting…Forecasts from VAR models are quite flexible because they can be made conditional on the potential future paths of specified variables in the model*" (Zivot & Wang 2006).

Batchelor, Alizadeh and Visvikis (2003) compared several models such as VAR model, vector error correction model (VECM) and unary ARIMA time series model, and then discern that VECM is more appropriate to describe spot prices and FFA prices than VAR model and unary ARIMA time series model (Batchelor, Alizadeh & Visvikis 2003). However, unary ARIMA time series model can make a better long-term forecast on forward prices than other models. Hence, with an appropriate model, the ability of predicting spot price by forward prices can be presented accurately. Therefore participants in this market can make more effective decisions. However, forward freight rates cannot be predicted by spot freight rates. The participants can obtain information of spot price trends even without hedging with FFA, but only by collecting and analyzing FFA price (Batchelor, Alizadeh & Visvikis 2003).

2.6 Conclusion

In this paper, a number of valuable literatures on tanker shipping industry, spot freight rate market and FFA market as well as several econometrical articles were reviewed. Currently the author has a preliminary knowledge of tanker freight market, FFA and price discovery function. Furthermore, by comparing various econometrical models introduced in literatures, the author determined VAR model as the main research methodology to analyze the price discovery function in tanker FFA market.

Chapter 3 An Analysis of Tanker Freight Market

3.1 Introduction

In order to investigate the price discovery function in tanker FFA market, the author first analyzed the characteristics of tanker freight market in Section 3.2. Afterwards, the author had an overview of the current status of tanker freight market in Section 3.3. In Section 3.4, the author analyzes the fluctuation of tanker freight rates. More specifically, the reasons why freight rates rose and fell in certain periods are analyzed respectively. In this chapter, qualitative analysis is carried out with the help of a number of data and figures. This analysis provides a comprehensive understanding of the objectives of the thesis as well as a good foundation for further quantitative analysis.

3.2 Characteristics of Tanker Freight Market

3.2.1 Great market volatility

Tanker freight market is an essential indicator of global economy and politics. This is mainly because oil trade volume is relatively sensitive to economic and political variables whilst oil trade is the key factor of tanker freight market. Conversely, significant economic fluctuation or political events give rise to ups and downs in tanker freight market. For instance, there was a severe global economic recession in 1992. America and Japan as well as other economic giants suffered dramatic slump at that time. This led to great recession in tanker freight market. The tanker freight rates fell to its lowest level.

3.2.2 Monopoly of supply of goods

Tanker freight market is not perfectly competitive due to the monopolization of cargo owners. The global top 50 oil firms possess more than 60% of oil and gas reserves, yields refining capacity. Thus these firms also control the global oil trade. Compared with dry bulk cargo market, the number of tanker charterers, such as giant oil companies, national oil companies and oil traders, is relatively small. If we look at the configuration of tanker charterers, we could discern that these charterers are large in scale, strong financial strength and dominate the global oil market. Nowadays, oil trading tends to be public; increasing volume of oil is traded in between suppliers and customers directly. Furthermore, these giants most have their own fleets, dedicated terminals and agencies. Therefore, major cargoes are transported through their own networks. Only a small ratio of cargoes is put on chartering market. It is difficult for simple tanker fleets without global networks to survive in this highly competitive market.

3.2.3 Long-term contracts

Due to the great volatility of tanker freight rates, most oil tanker companies prefer signing long-term contracts with importers and exporters so as to guarantee steady supply of cargoes and manage risks. Thus long-term contracts are ubiquitously adopted by oil tanker companies in the market. These long-term contracts could be divided into two categories: one is long-term contract signed for currently deployed tankers; the other one is to sign a long-term contract for a certain oil tanker before its construction. The latter contract not only guarantees the cargo supply, but also provides sufficient capital investment.

3.2.4 Charterers dominate the market

Tanker owners could hardly determine the charterers due to the monopoly of giant oil firms. They could only choose contract templates and special clauses offered by those giants regardless of the level of the market. For instance, Shell, BP and TEXMCO all have their own fixed contract templates. In practice, these contracts and clauses are not biased towards either side since the oil firms also use the contract as ship owners some time. However, the contacts could barely be amended according to ship owners' requirements during negotiation.

3.2.5 Rigorous safety inspection regime

In order to guarantee the operation of tankers, the ship owners have to accept rigorous safety inspections offered by oil firms. This type of inspection has been conducted in recent years and tends to be increasingly rigorous due to continuous oil tanker pollution accidents.

3.2.6 Emerging competitors

The parties in tanker freight market are adjusting business strategies and seeking strategic alliances along with the volatility of tanker freight rates and fierce competition. The generation and development of strategic aliens around the world are changing the original situation and rules of international competition gradually. The competitions in between enterprises turn to be set in between aliens.

3.3 Overview of Tanker Freight Market

3.3.1 Status of Tanker Freight Market

Accompanying with the sharp rise of demand for oil and other liquid bulk products, the size of global tanker fleets has grown dramatically for decades. Nowadays, along with the technical progress, tanker shipping provides economical and secure liquid bulk transport services around the world. Tanker is considered as the most cost-effective mode of liquid bulk transportation, with only US$0.02 per gallon at the pump (Huber 2001). Currently, there are 4 vessel types, namely Panamax, Aframax, Suezmax, VLCC and ULCC in line with the size of vessel.

In line with the description from Makan (2013), oil tanker trade has boomed with the highest growth rate over the past decade due to the shift of international trading from the US to other emerging economies. Thus crude oil was shipped much longer distances as more oil tankers changing their destinations to India and China instead of the US (Makan 2013).

The figure below describes the aforesaid growth clearly. Despite of slight declines due to some events such as oil crisis in 2002, the main trend of the global oil trade was upward. Last year the trading volume even reached to around 7.8 trillion tonne-miles.

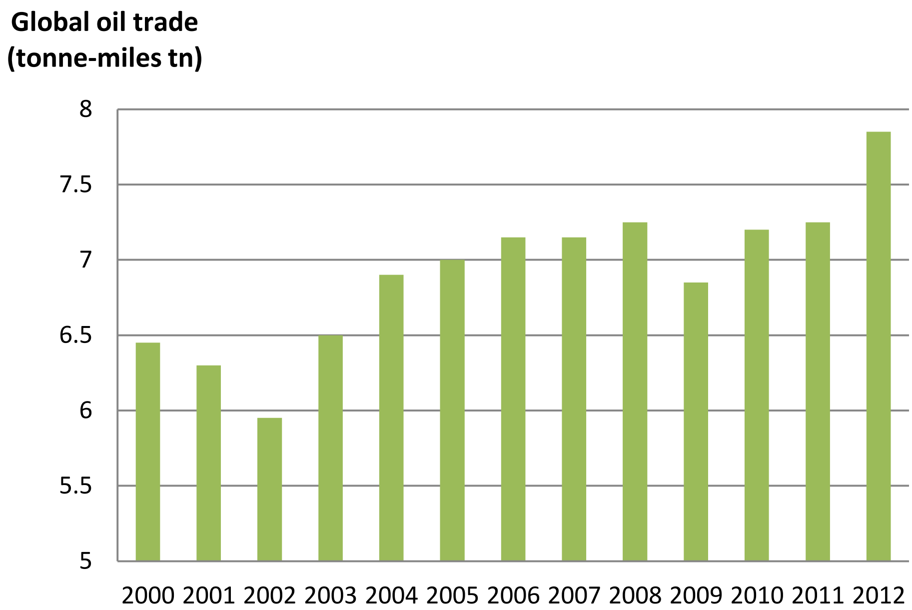

Figure 3-1 Global Trade in Oil
Source: Compiled by author based on the data from Icap Shipping
Notes:

- Tonne-mile reflects both the volume traded and the distance travelled jointly.
- Tn is the abbreviation of trillion.

3.3.2 An Analysis of the Fluctuation of Tanker Freight Rates

As the author mentioned in Section 3.2.1, tanker freight rate is very sensitive to various economic and political factors such that it has been highly volatile during the past decade. Considering the global oversupply of oil, OPEC declared to reduce the output of 120 barrels per day in the end of 2006 (Liu 2008). Affected by this as well as the slack season of demand for oil in Western, the tanker freight market suffered turbulent sessions continuously during the first half of 2007. The BDTI on June 29th, 2007 is 1041, falling 9.1% from the average BDTI in the first half of the year (1161). However, from the beginning of the latter half of 2007, the tanker freight rates turned to rebound from the bottom. The following figure illustrates the daily BDTI from June 2006 to June 2012. The author noticed that, from January to November in 2007, the tanker freight market stayed depressed with an average BDTI of 1073. However, the BDTI started to soar since December 2007 by sudden and reach 2279 on December 19th, 2007.

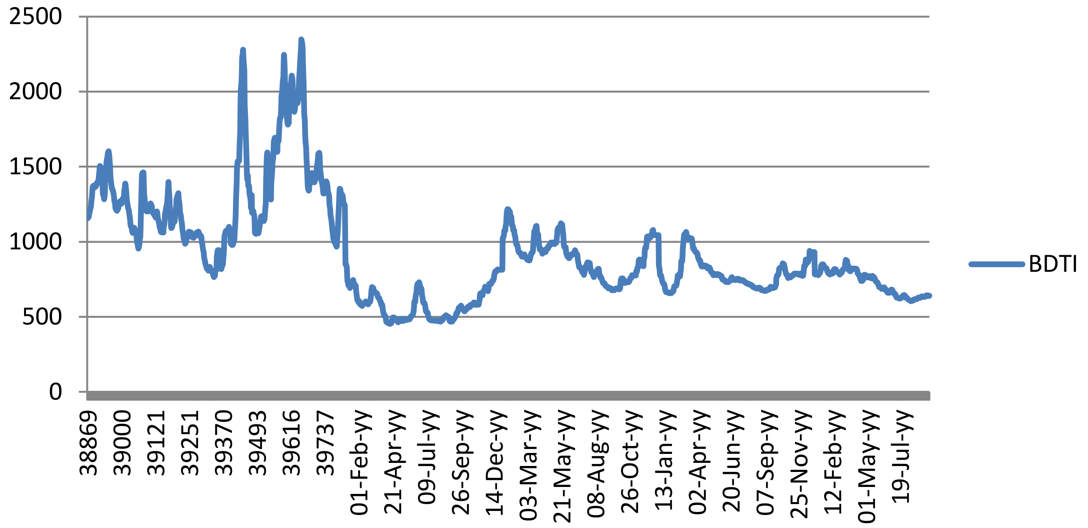

Figure 3-2 BDTI from June 2006 to June 2012
Source: compiled by author based on the data from Baltic Exchange

The aforesaid great volatility is only one glance of the whole history of tanker freight market. This dramatic fluctuation is believed to be inevitable but also brings huge uncertainties and challenges to the participants in this market. Such being the case, what exactly give rise to the fluctuation? The author first considered the reasons for the depression of tanker freight market.

The boom of the global demand for oil in recent years led to the growth of tanker fleet size; in 2010, the tanker trade volume reached to 2,767 million tons due to growth in demand for energy commodities (Lun et al. 2013). As Lun *et al* (2013) stated, "*the increased cargo volume in the tanker market leads shipping firms to adjust their supply by building new ships in the new building market, and acquiring second-hand vessels in the sale and purchase market*". The oversupply of tanker capacity is considered as the main reason that gives rise to the depression of tanker freight market. By the year of 2007, the amount of VLCC had been 501 with capacity of 147 million dead weight tonnage (Mysteel 2008). The overall tanker capacity was 390 million dead weight tonnages at that time. Until 2008, the surplus of tanker capacity supply has reached 11.1 million tons, and this situation has been more extreme (Leonda 2012). By the end of 2009, in order to control the supply of tanker capacity, considerable tankers were laid up. According to the report from SSY, 168 lay-up tankers were used to store oil by cargo owners and traders. The overall stored volume was 23.80 million dead weight tonnages, which accounted for 5.9% of the global tanker capacity (Netsease 2010).

Lun and Quadus (2009) asserted that demand for sea tanker shipping services is a type derived demand, which should be determined by seaborne trade volume (Lun & Quaddus 2009). However, the sustained high level of oil price restrains the demand for oil to an extent.

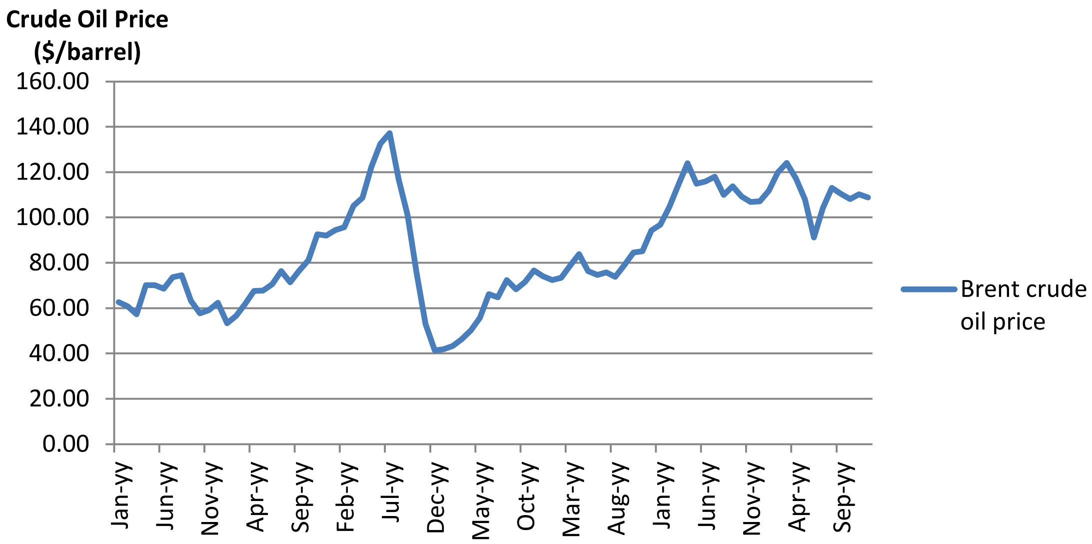

Figure 3-3 Brent crude oil price from January 2006 to December 2012
Source: compiled by author based on the data from Clarksons

The crude oil prices from January 2006 to December 2012 were collected and used to construct the above figure. In accordance with this figure, the author found that, the crude oil price had been climbing rapidly since the end of 2006 and once reached to around 140 $ per barrel. Notwithstanding suffering a significant slump in 2008, the price bottomed out soon from then on. This upward trend was kept for a fairly long time. Moreover, though with slight fluctuation, the price had stayed at a relatively high level until the end of 2012. In comparison with Figure 3-2, Figure 3-3 appears to reveal basically opposite trends. Hence, the author argued that the high level of the oil price plays an essential role on restraining tanker freight rates.

In addition, the pipeline transportation for oil was promoted in many regions. This brought a new pattern for the cargo owners and traders to transport their products. However, it is obviously that a portion of seaborne traded oil would be transported by pipeline instead of tankers. Hence, the demand for tanker shipping services declined, and this in turn aggravated the oversupply of tanker capacity.

The above explained why tanker freight rates encountered depression from two perspectives. From here on, the author attempted to analyze why tanker freight rates rebounded.

Comparing Figure 3-2 with Figure 3-3 again, the author noticed that one main feature of the tanker freight market in 2007 is converse trends of freight rates and crude oil price. The BDTI in 2007 did not rebound until the fourth quarter. This is typically due to the coming of peak season of oil demand. The increasing demand for tanker shipping services led to the rebound of freight rates to some extent. At the same time, single-hulled tankers started to be scrapped whilst new tankers cannot be deployed immediately. This also alleviated the situation of the oversupply of tanker capacity. When focusing on specific route, we can discern that the Worldscale rate on route Middle Eastern Gulf to Japan by VLCC rose from 60 to 180 in just two weeks, which corresponds to a rise from 30 thousand US dollars to around 140 thousand US dollars.

In addition to the seasonal reason, the author also considered two other factors:

1. Speculation on forward freight agreement market

   For the purpose of hedging, international refining enterprises purchased considerable amount of FFA contracts of relatively high freight rates in 2007. However, the freight rates in tanker freight market dropped significantly before the third quarter of 2007. If this situation was kept till the end the year, the maturing contracts would brought huge losses. Hence, these enterprises attempted to push up the forward price by speculating FFA contracts, and this in turn, brought the rise in spot market. Thus, the speculation of FFA contracts is considered as the reason for the rebound of freight rates.

2. Renovation of single-hulled VLCC

   Due to the implement of the single-hulled tanker phase-out scheme by IMO, many single-hulled VLCCs were transformed to bulk carriers (IMO 2010). Considering the boom of dry bulk market in 2007, more tankers were transformed to fulfil the demand for dry bulk shipping services. Therefore, a huge amount of tanker capacity was shifted to dry bulk market. This in turn tempered the oversupply of tanker capacity and drove freight rates to an upward trend.

3.4 Conclusion

In this chapter, the author first analyzed the characteristics of tanker freight market and then overviewed its status. Generally speaking, this market is not perfectly competitive and reveals sensitive to various economic and political factors. The great volatility of freight rates is also a main feature of tanker freight market. Hence, the author further analyzed the fluctuation of freight rates and concluded that:

- The freight rates are impacted by the seasonal demands for oil;
- The promotion of pipeline transportation shared a portion of the volume of seaborne trading oil. This exacerbated the oversupply of tanker capacity;
- Oil price impacts the oil trading significantly and in turn influence the demand for tanker shipping services;
- Single-hulled tanker phase-out scheme alleviated the oversupply of tanker capacity to an extent.

Chapter 4 An Analysis of Tanker Forward Freight Agreement Market

4.1 Introduction

Tanker forward freight agreement (FFA) and its price discovery function are the main objects of this thesis. Hence, before introducing certain quantitative methods to study the relationship between spot freight rates and forward prices specifically, the author first analyzed tanker forward freight agreement market and the price discovery function from a qualitative perspective. Firstly, in Section 4.2, the author had an overview of FFA and tanker FFA market. Afterwards, the specific process of transaction of FFA contracts was studied in Section 4.3. Last but not least, the author focused on the price discovery function of tanker FFA and its effects in tanker forward market in Section 4.4. By the above analyses, the author would have a clear perception of tanker FFA market and p preliminary understanding of the relationship between spot market and forward market.

4.2 Overview of Tanker Forward Freight Agreement Market

4.2.1 Emergence of Forward Freight Agreement

The international dry bulk shipping market was established on the basis of tramp shipping. Hence, the dry bulk shipping market is basically a perfectly competitive market. The freight rate in this market is determined by various factors such as supply and demand, weather and political events. Thus it is volatile all the time.

One single ship owner or cargo owner is incapable to the great volatility of freight rates but only accept it passively. This undoubtedly brought huge risks and uncertainties for the participants in dry bulk market. Dry bulk operators attempted to control these risks by long-term contracts of affreightment and time charter party. However, these conventional measures were considered as either not flexible or reliable. Hence, under this circumstance, BFI were created along with BIFFEX.

Website Economic Times described the term BFI as: "*it is a weighted average based on 11 international ship routes and three commodities - coal, iron ore and grain. It reflects on the freight and charter rates of these commodities on these routes*" (Economictimes 2013). Harris (2001) defined BIFFEX contact as a type of derivatives contract which is settled against the BFI. This contract was first adopted in 1985 and was finally withdrawn in 2002 due to lack of liquidity (Harris 2001).

The conception of forward freight agreement was first proposed by Clarksons in 1991. However, there is not a formal definition of the FFA. Hence, with the Dinwoodie and Morris's article (2010) and term description in Wikipedia (2012) as references, the author summarized the properties of FFA as: FFA is a type of principal-to-principal agreement, which is typically traded over the counter; its underlying asset is shipping service, which is non-storable (Dinwoodie & Morris 2010); it is used by market participants to hedge against the volatility of freight rates as well as speculation due to its nature of financial instrument; the contracts determine a price in a particular freight route on a particular date and will finally be settled based on corresponding freight index (Wikipedia 2012). An FFA contract can be settled more precisely than BIFFEX contracts. Moreover, it is also easy to execute and the indices on which it was built are creditable in shipping markets. Hence, ever since FFA was introduced, the volume of FFA contracts traded has surged and this trend is believed to stay for a further period.

4.2.2 Development of Tanker Forward Freight Agreement

Glen and Martin stated that "*tanker freight market is renowned for exposing participants to varying risks*" (Glen & Martin 1998). Hence, financial instruments, such as FFA contracts used in dry bulk market, were also expected in tanker market due to the same purpose of hedging freight risks and guarantee freight revenue (Dinwoodie & Morris 2010). The first tanker freight derivatives contract was constituted in 1986, whereas it did not last for a long time but suspended indefinitely soon (Wikipedia 2008). By 1994, the first tanker FFA contract was signed by Cargill and British Petroleum on the basis of the assessment of London Tanker Brokers' Panel (Intertanko 2005).

Nowadays, the tanker FFAs are traded on several standard tanker shipping routes as well as a number of specific routes which can be settled the same with standard routes by negotiation. The Baltic Exchange issued two indices for dirty tanker routes and clean tanker routes respectively, namely Baltic Dirty Tanker Index (BDTI) and the Baltic Clean Tanker Index (BCTI) (Algeny 2008).

Figure 4-1 depicts the volumes of tanker FFA contracts fixed over ten years. Before 2001, the annual volume of FFA contracts was less than 10 million tones and barely had any growth. However, the volume has been surging rapidly and steadily since then and reached to around 370 million tonnes in 2007.

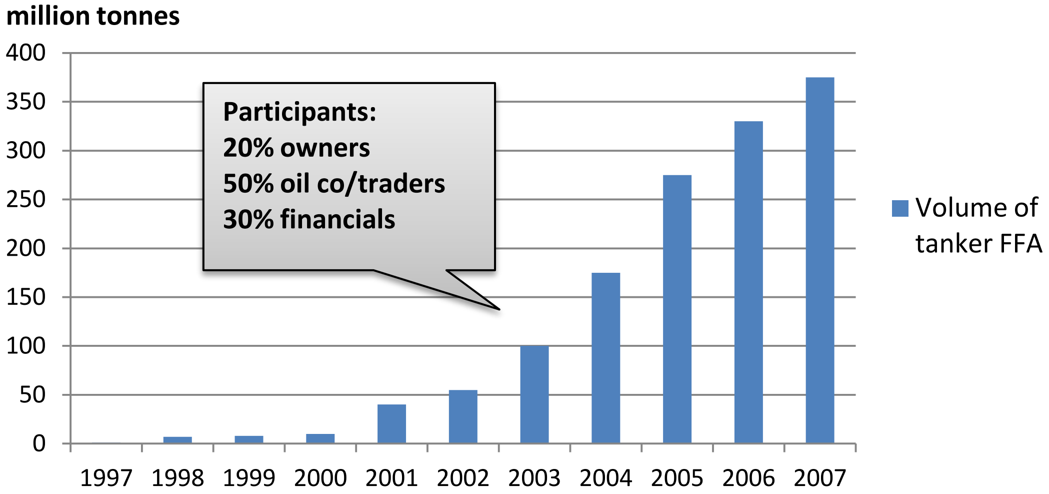

Figure 4-1 Volume of Tanker FFA Fixed from 1997 to 2007
Source: Simpson Spence & Young Futures

A table from Teekay, Imarex and Clarkson Capital generally describes the activity of tanker FFA trading in various tanker routes in 2005. Amongst those tanker routes, the dirty tanker route TD3 has the most active tanker FFA contracts trading following by TD5 and TD7, in other words, the liquidity of the forward market in TD3 route is the strongest. As for clean tanker routes, the forward markets in TC2 and TC4 perform actively the most. The specific contents of the aforesaid table are shown in Table 4-1.

Table 4-1 Tanker FFA Contracts in Different Tanker Shipping Routes

Route	Segment	Trade	Size	Trading unit	Price quotation	Index
TD 3	VLCC	AG – Japan (Ras Tanura - Chiba)	250,000 mt	1000 mt	Worldscale	Baltic
TD 4	VLCC	West Africa – USG (Bonny - Loop)	260,000 mt	1000 mt	Worldscale	Baltic
TD 5	Suezmax	West Africa – USAC (Bonny - Philadelphia)	130,000 mt	1000 mt	Worldscale	Baltic
TD 7	Aframax	North Sea – Cont (Sullon Voe – W. Haven)	80,000 mt	1000 mt	Worldscale	Baltic
TD 9	Aframax	Caribs - USG (Puerto La Cruz – Corpus Christi)	70,000 mt	1000 mt	Worldscale	Baltic
TD 10	Panamax	Caribs - USAC (Puerto La Cruz - Philadelphia)	50,000 mt	1000 mt	Worldscale	Baltic
TC 1	LR II	AG – Japan (Ras Tanura - Chiba)	75,000 mt	1000 mt	Worldscale	Baltic
TC 2	MR	Cont – USAC (R'dam - Philadelphia)	30,000 mt	1000 mt	Worldscale	Baltic
TC 4	MR	Singapore - Chiba	30,000 mt	1000 mt	Worldscale	Platts

Source: Teekay, Imarex & Clarkson Capital in 2005

Note:

- The rows with background color represent the tanker routes which have the most liquid contracts.

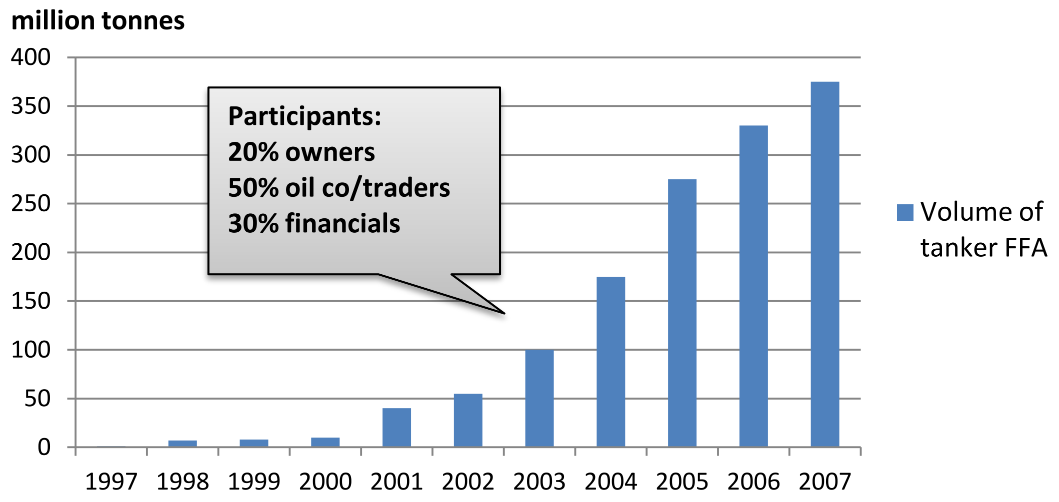

Figure 4-1 Volume of Tanker FFA Fixed from 1997 to 2007
Source: Simpson Spence & Young Futures

4.2.3 Overview of Participants in Tanker Forward Freight Agreement Market

Undoubtedly, FFAs are typically used to hedge freight risks as a type of freight futures contract. However, another function of FFA – speculation – should not be neglected. A functioning derivatives market also needs speculators and arbitrageurs to ensure liquidity so as to maintain the underlying asset values of the contracts (Dinwoodie & Morris 2010). Hence in this section, the author had an overview of the participants in tanker FFA market.

- Tanker shipping companies

As the major participants in tanker FFA market, tanker shipping companies are willing to manage freight exposures and lock-in future revenues by purchasing FFA contracts. It is flexible for these companies to react swiftly to spot market volatility rather than time charter. Additionally, forward market provides more information on future spot price relative to spot market due to the effects of price discovery process of forward prices. Therefore, by means of this, shipping companies can make strategies in advance and allocate their capacities more reasonably.

- Trading companies

Trading companies, who are the main counterparties of FFAs, also reveal powerless to the great volatility of freight rates. Likewise, for the purposes of controlling costs, these companies are also willing to hedging risks through freight derivatives market. Thus, FFA tends to be the best option for trading companies due to its flexibility and reliability.

- Financial institutions

FFA markets have attracted increasing attentions from international financial institutions and companies over recent years. Financial magnates such as Morgan

Stanley and Deutsche Bank were involved into this market in succession. On the one hand, they provide financing services for the counterparties of FFAs. On the other hand, they make contrarian investments against exposures to circumvent their own risks. Furthermore, FFAs are also used to constitute portfolios. For instance, as the author mentioned in Section 1.1, investment banks such as Morgan Stanley and Goldman performed quite actively in wet bulk derivatives market, which is highly correlated with energy commodities.

- Oil companies and other energy companies

The correlation between energy commodities' price and tanker freight rates has appeared to be increasingly high over recent years. Hence, as the cargo owner mostly with self-owned tanker fleets, those oil companies and other energy companies such as Shell and BP participated in freight derivatives market more actively other than other energy commodity derivatives market. Tanker FFAs brought them a critical instrument to lock-in shipping cost, and in turn, participate in market competition more reasonably.

4.3 Transaction of Tanker Forward Freight Agreement

4.3.1 Process of Forward Freight Agreement Transaction

There are mainly two modes of transaction of FFA currently, namely over-the-counter (OTC) transaction and transaction on exchange. FFA has been an OTC product since it was introduced. Thus it was traded mostly over the counter rather than on an exchange (Drewry 1997).

FFA is a type of futures contract that the counterparties are responsible to honor the agreement at a pre-specified future date (Dinwoodie & Morris 2010). The underlying asset of FFA is shipping service, which is non-storable (Gray 1990). Counterparties of an FFA contract would generally keep their identities confidential until the deal is concluded (Dinwoodie & Morris 2010). Mahon (1997) elaborated the process of cash settlement of an FFA as "*it is based on future price movements of Worldscale rates calculated for a particular route, cargo-type and vessel-size, uses BITR and other specialists for 15 standardized routes where a panel of shipbrokers provides average daily assessments over a defined period, serving as the future price for settlement purposes*" (Mahon 1997).

However, there inevitably exist credit risks during the process of OTC transaction due to the property of principal-to-principal agreement. Shipbrokers only act as intermediaries but not responsible for honoring agreements by counterparties. Nowadays, settlement can be conducted in formal clearing house such as London Clearing House (LSH) such that credit risks are significantly eliminated. Figure 4-2 depicts this process clearly.

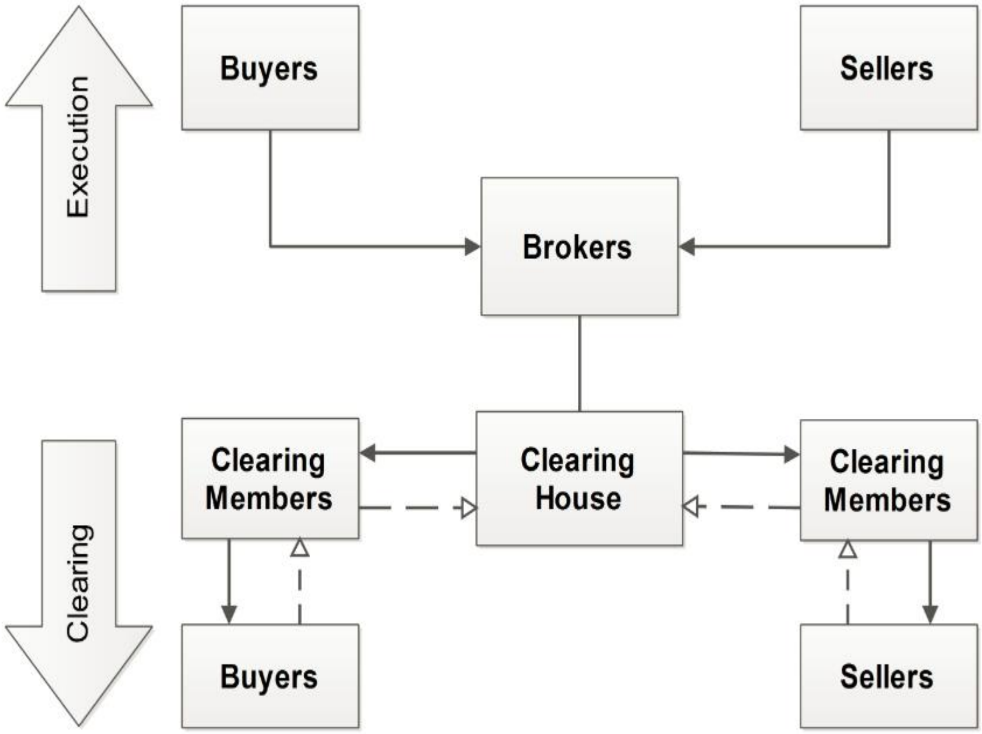

Figure 4-2 Process of Forward Freight Agreement Transaction
Source: Simpson Spence & Young Future

4.3.2 Forward Freight Agreement Trading Examples

Apparently, a decline of freight rates in tanker freight market would reduce carriers' freight revenue while rising rates would raise shippers' sea transport costs (Dinwoodie & Morris 2010). Kavussanos and Nomikos explained the principle of FFA trading as "*by transferring their risk to counterparty, the ship owner will sell and charterer will buy an FFA. Both parties require an 'equal but opposite' position to cover the freight to be hedged against*" (Kavussanos & Nomikos 2003). In this section, the author simulated 3 situations as examples to elaborate the transaction of FFA.

Prior to examples, the author first introduced the main elements of a standard FFA contract. Currently, FFABA 2005, which is widely used as a standard form, was created for the purpose of eliminating the risk related deficiencies of conventional derivatives contract (OlympicVessels 2013). The main terms of FFABA 2005 are listed below:

Table 4-2 Main terms of FFABA 2005

Term	Example
Specified route	TD3
Vessel type	VLCC; Suezmax
Contract price	$25,000 per day; $7.50/mt
Quantity	30 days; 20,000 mt
Period	Month; quarter; year
Settlement date	31/01/2011
Settlement price	Average of the index days in January
Settlement value	(contract price - settlement price) * quantity
Clearing	LCH; NOS

Source: Simpson Spence & Young Future in 2011

Afterwards, the author further analyzed the application of FFA in tanker routes by taking 3 examples.

Example 1: Hedge on time charter party

In early July 2007, one VLCC, which was owned by ship owner A, would be redelivered after two months, namely in the end of August 2008, due to the expiration of time charter party. When this VLCC was redelivered, ship owner A was keen to deploy this vessel in TD3 route for one voyage. However, A concerned that the spot freight rate after 8 weeks would decrease. Hence, he was willing to hedge this risk through FFA. The spot freight rate was $11,150 per day at that time. Thus ship owner A determined to sell an FFA contract of 60 days at $10,050 per day. In this case, under the circumstance that the spot freight rate fell to $7,380 per day, the specific returns of spot market and FFA market are listed in following table:

Table 4-3 Returns of Spot Market and FFA Market

Spot market		**FFA market**	
Spot freight rate in TD3 on Jul. 2nd, 2007:	$11,150 per day	**Contract price of 60 days in TD3:**	$10,050 per day
Expected freight revenue:	11150*60=$669,000		
Spot freight rate in TD3 on Aug. 31st, 2007:	$7,380 per day	**August Settlement :**	$7,430 per day
Real freight revenue:	7,380*60=$442,800	**Settlement value:**	(10,050-7,430)*60= $157,200
Losses in spot market:	$669,000-$442,800= $226,200		
	Overall payoff:	157,200-226,200=$69,000	

Source: compiled by author

Suppose that ship owner A did not hedge the risk of spot market, he would have lost $226,200 in the end of August 2007. However, with the help of FFA, this loss was controlled at a relatively low level. Thus in this case, ship owner reduced the losses caused by the decline of freight rate through FFA contracts effectively.

Example 2: hedge on voyage

Ship owner B was operating one Suezmax in 2006. Due to the decline of crude oil price, B concerned that the corresponding freight rate would fall consequently. The freight rate in TD5 on March 15th, 2006 was $8.3/mt, whilst B was keen to lock in the freight rate in 2007 at $7.9/mt and hedge for 50%, namely 65,000mt of crude oil. With a shipbroker acting as an intermediary, ship owner B concluded an FFA contract with company C. the main terms of the contract are presented as follows:

Table 4-4 Main terms of the FFA Contract in Example 1

Term	Content	Term	Content
Buyer:	Ship owner B	**Seller:**	Company C
Route:	TD5	**Quantity:**	65,000 mt
Contract price:	$7.85/mt	**Period:**	Year of 2007
Settlement date:	31/01/2007; 30/04/2007; 30/10/2007; 31/12/2007	**Settlement:**	Average of last 7 index days of each Quarter
Commission:	0.25%		

Source: compiled by author

As the ship owner predicted, the spot freight rate declined in 2007. Therefore, after the settlement dates, he earned profits by this FFA contract and locked in freight rates successfully. The settlements of the FFA contract are shown below:

Table 4-5 Settlement of FFA contract

Period	Settlement	Price differential	Profit
1st Quarter	$ 7.10	+ $ 0.75	0.75 * 65,000 = $ 48,750
2nd Quarter	$ 7.15	+ $ 0.70	0.70 * 65,000 = $ 45,500
3rd Quarter	$ 7.30	+ $ 0.55	0.75 * 65,000 = $ 35,750
4th Quarter	$ 7.35	+ $ 0.50	0.75 * 65,000 = $ 32,500
		Commission:	4 * $7.85 * 65,000mt * 0.25% = $5,102.5
		Total profit:	$ 157,397.5

Source: compiled by author

Example 3: lock in profits based on Example 2

On the basis of Example 2, by mid-July 2007 the freight rate in TD5 is $7.2/mt. Ship owner B believed that this would be the lowest price in 2007. Therefore, he determined to purchase one FFA contract of July and one of October with the contract prices of $7.20/mt and $7.25/mt respectively. Thus the profit of the third quarter ($0.65/mt) and the profit of the fourth quarter ($0.60/mt) were locked in. Based on a precise market analysis as well as a reasonable application of FFA, the ship owner further locked in more profit than he did in Example 2. The settlements of FFA contracts with new strategy are listed below:

Table 4-6 Settlements of FFA Contracts Based on New Strategy

Period	Settlement	Price differential with original contract	Price differential with contract of July	Price differential with contract of October	Total	Profit
1st Quarter	$ 7.10	+ $ 0.75			$ 0.75	$ 48,750
2nd Quarter	$ 7.15	+ $ 0.70			$ 0.70	$ 45,500
3rd Quarter	$ 7.30	+ $ 0.55	+ $ 0.10		$ 0.65	$ 42,250
4th Quarter	$ 7.35	+ $ 0.50		+ $ 0.10	$ 0.60	$ 39,000
					Total profit:	$ 175,500

Source: compiled by author

4.3.3 Pros and Cons of the Application of Forward Freight Agreement

So far the author has gone over the tanker forward market and particularly learnt the process of the transaction of FFA with specific examples. During this process, some advantages were revealed clearly as well as some deficiencies. The author summarized these pros and cons as follows:

Advantages

1. FFA can be used both for hedge and speculation, with which enterprises can manage risks flexibly and swiftly.

2. As a paper derivatives contract, FFA is traded with underlying asset of shipping service, but not related to the deployment of physical assets. Hence enterprises can operate there assets without concerning the transaction of FFA.

3. FFA market is believed to have a good price discovery function to guide spot market to some extent. Thus, unlike BIFFEX futures, FFA barely encounters the situation that the difference between fluctuations of futures index and spot freight index is significant. Therefore, it performs more efficitve on hedge risks.

4. FFA is a principal-to-principal agreement ,which can be concluded over-the-counter rather than on exchange. Hence the transaction of FFA is flexible with relatively low transation costs.

5. Certain vessel type,shipping routes and trading quantity etc. can be specified in FFA contracts on the basis of negotiation. Enterprises can conclude contracts with diversified choises according to the actual situation. Thus FFA has strong pertinence.

Deficiencies

1. FFA contracts could be concluded principal to principal, that is to say, counterparties should accept each other's credit worthiness. This would bring underlying credit risks. Even though counterparties trade with shipbrokers as their intermidiaries, those shipbrokers are not responsible for the execution of the contracts.

2. Settlement of FFA is dependent on BFI standard routes to some extent. Hence, if there is significant difference between standard route and real route, then the corrsponding quote can hardly be matched in that market.

All in all, despite of some deficiencies, FFA is believed as a functional financial instrunment for the participants in tanker market to hedge freight risks and lock in future revenues.

4.4 Price Discovery Function of Forward Market

Kavussanos and Nomikos described price discovery as "*it is the process of revealing information about future spot prices through the futures market*" (Kavussanos & Nomikos 2003). A principal-to-principal transaction of FFA is essentially a "bet" on whether freight rates of a certain type of vessel on a specified route during a certain period would be higher or lower than the contract price (OlympicVessels 2013). Hence, forward price is not fixed artificially, but is discovered through fair and free "bet" on the basis of supply and demand in spot and forward market. It is deemed that forward price contains useful information about subsequent spot prices, (Kavussanos & Visvikis 2004), and this information is transmitted by various means and in turn provides guidance for the transactions between buyers and sellers. Results from Kavussanos and Nomikos (2003) asserted that, "*despite the non-storable nature of the market, FFA prices contribute to the discovery of new information in the spot market, and can be equally important as sources of information as spot prices are in commodity and financial markets*" (Kavussanos & Nomikos 2003). In addition, the results also proved that OTC contracts discover information faster than spot markets due to some trading friction such as higher transaction costs in spot markets (Kavussanos & Nomikos 2003). In brief, price discovery function is believed as an important mean to discover real and comprehensive price which can reflect the supply-demand relationship dynamically based on fair and open transactions in market. The main implications of price discovery function are summarized as follows:

1. Effective competition in market

Effective cometition is regarded as a vital premise of price discovery process, or else, the generated price cannot truly reflect the supply-demand relationship in certain market.

2. Efficiency and liquidity in market

   This indicates that each information influencing supply and demand on market should be transitted and can be obtained by all participants. Thus information asymmetry barely exist and counterparties could be matched reasonably and swiftly.

3. Standardaization

   Transactions are standardized and processed in order. No monopolies and deceits exist in market.

Despite of some deficiencies, by which spot market is deemed as incapable to discover price, it is undeniable that there exists lead-lag relationship between spot market and forward market. Kavussanos and Visvikis (2004) explained this lead-lag relationship as "*it is a relationship between the price movements of derivatives returns and the underlying spot market returns that illustrates how fast one market reflects new information relative to the other, and how well the two markets are linked*" (Kavussanos & Visvikis 2004).

In general, spot price and forward price constitute a price system jointly. Price discovery process is based on the combined effects of both spot price and forward price. Hence, only if these two prices are integrated to reflect markets, does the price discovery process have practical economic significance.

4.5 Conclusion

In this chapter, the author analyzed tanker forward freight agreement market systematically. In particular, specific process of the transaction of FFA and its development were elaborated. Last but not least, the author also focused on the object of this paper, i.e. price discovery function. With the above analyses, the author concluded as follows:

1. Forward freight agreement is a type of principal-to-princial agreement with underlying asset of shipping service, which is non-sotrable. It is traded over-the-counter rather than on exchange by the participants in derivatives market and is typically used for hedging freight risks and specluation.

2. FFA, which was created for dry bulk shipping initially, is now also prevailing in tanker routes. It provides an important financial intrument for market participants to avoid riks and make better operating strategies.

3. Price discovery function is an important function of foward market. It can reveal information about future spot prices through the futures market. notwithstanding the deficiencies of spot market, spot price and foward price constitute the market price system.

Chapter 5 Introduction of Vector Autoregressive (VAR) Model

5.1 Introduction

Conventional econometric methods aim to construct models to describe the correlations in between economic variables on the basis of economic theories. However, these theories are typically not sufficient to demonstrate the dynamic structure in between the variables explicitly. Furthermore, endogenous variables, which would appear on both the right-hand side and the left-hand side of equations of econometric models, make forecasting more complicated. In order to overcome these defects, Sims advocated Vector Autoregressive (VAR) Model, which will also be introduced in this paper.

5.2 General Expression of VAR Model

Vector autoregression (VAR) construct models on the basis of statistical properties. It generalizes the univariate autoregression (AR) models by introducing vectors, which consist of endogenous variables, underlying multivariate time series. Piroli, Ciaian and Kancs (2012) described the VAR model as "*all variables in a VAR are treated symmetrically; each variable has an equation explaining its evolution based on its own lags and the lags of the other model variables*" (Piroli, Ciaian & Kancs 2012).

The mathematical expression of VAR (p) is

$$y_t = c + A_1 y_{t-1} + A_2 y_{t-2} + \cdots + A_p y_{t-p} + e_t \quad t = 1, 2, 3 \ldots, T$$

where y_t is a $k \times 1$ vector of endogenous variables, T is the number of samples and p stands for p lags. A_i is a time-invariant $k \times k$ matrix of coefficients and e_t is a $k \times 1$ vector of error terms. e_t needs to satisfy:

- $E(e_t) = 0$, the mean of error terms is 0;
- $E(e_t e_t') = \Omega$,
  the contemporaneous covariance matrix of error terms is Ω, which is a $k \times k$ positive − semidefinite matrix;
- $E(e_t e_{t-k}') = 0$,
  there is no correlation in between error terms across time for any non − zero k.

5.3 Stationarity Test of Time Series

5.3.1Stationarity

Loosely speaking, stationarity for a time series model typically means that the statistical properties of the model do not change over time. In more detail, mean and variance of a time series variable y_t do not depend on the time t. In an empirical time series analysis, if we set up a regression model regardless of stationary time series or non-stationary time series, we would run the risk of generating a spurious regression, i.e. there is no correlation in between variables notwithstanding, the results of the regression would reveal correlated. Type of model is apparently not valid. Therefore, it is essential to test the stationarity of the time series in this paper before we analyze data with VAR model.

In particular, we define a time series variable y_t as integrated of order d, which is expressed with $y_t \sim I(d)$, if non-stationarity can be removed by differencing the variable d times while the variable remains non-stationary after d – 1 times of differencing. If y_t is stationary without any differencing process, it is called integrated of order 0, denoted by $y_t \sim I(0)$.

5.3.2 Unit Root Test

Unit root test is known as the standard method of testing stationarity for time series. A unit root indicates that the stationarity of a certain time series is determined by the characteristic function which can reflect the feature of this time series. Hence, if the roots of this characteristic equation all locate outside unit circle, then the corresponding time series is stationary; otherwise, this time series is non-stationary (Wikipedia 2013).

The main techniques of unit root test are Augmented Dickey-Fuller Test (ADF), Dickey-Fuller Test with GLS (DFGLS), Phillips-Perron Test (PP), and Ng and Perron Test (NP), etc. In this paper we shall use ADF test as the main method of stationary test.

ADF test is an augmented version of DF test which was developed by Dickey and Fuller in 1979. Since DF test neglects that there would be moving average terms amongst variables or there would be significant autocorrelation in residual terms, the results of the test could be misleading. Dickey and Fuller augmented DF test by introducing lag order of autoregressive process, whereby ADF test allows for high-order autoregression. This in turn, indicates that the lag length has to be determined when ADF test is employed.

The autoregressive processes tested by ADF are as below:

1. Without constants and trend terms:

$$\Delta y_t = \gamma y_{t-1} + \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + u_t$$

2. With constants but no trend terms:

$$\Delta y_t = \gamma y_{t-1} + a + \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + u_t$$

3. With constants and trend terms:

$$\Delta y_t = \gamma y_{t-1} + a + \delta t + \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + u_t$$

where, a is a constant, t is a trend term, δ is the coefficient for t, β is the coefficient for Δy_t and u_t is the residual term.

Thus, the unit root test is carried out under following hypotheses:

$$\begin{cases} \text{Null hypothesis } H_0: \gamma = 0 \\ \text{Alternative hypothesis } H_1: \gamma < 0 \end{cases}$$

More specifically, H_0 states that the tested time series has 1 unit root; H_1 stands for non-existence of unit roots, there is possibility that y_t includes constants and trend terms. If H_0 is rejected, we can conclude that there is no autocorrelation for residual terms, i.e. the tested time series has no unit root and is stationary; otherwise, this time series need to be differenced until it fulfils the criteria of stationarity. In this paper we shall apply t-test on coefficients to examine the hypotheses. The term p in aforementioned 3 autoregressive processes is the optimal lag order. This can effectively eliminate the problems incurred by residual terms.

5.4 Determination of the Lag Order p in VAR Model

Lag order p plays a vital role In a VAR model. In order to determine an optimal lag order, two aspects need to be taken into consideration comprehensively. On the one hand, the larger the lag order p is, the more precise the model is to demonstrate the dynamics of time series; on the other hand, the larger the lag order p is, the more coefficients are need to be estimated and the smaller the degree of freedom of the model is.

In this paper we shall use Akaike Information Criterion (AIC) and Schwarz Criterion (SC) to determine the lag order p. The results from these two methods will be compared and the relatively smaller lag order will be determined as the optimal one.

The processes of these two methods are as below:

$$\mathrm{AIC} = -\frac{2l}{T} + \frac{2n}{T}$$

$$\mathrm{SC} = -\frac{2l}{T} + \frac{n \ln T}{T}$$

Where $n = k(d + pk)$ is the sum of the estimated coefficients, k is the number of endogenous variables, T is the length of sample, d is the number of exogenous variables, p is lag order and $l = -\frac{Tk}{2}(1 + \ln 2\Pi) - \frac{T}{2}\ln|\hat{\Sigma}|$.

5.5 Johansen Cointegration Test

5.5.1 Cointegration

Cointegration is a statistical property of time series variables. It is possible that a linear combination of two or more non-stationary time series is stationary. If so, then we state that these time series are cointegrated. More formally, if the following criteria are satisfied:

1. $y_t \sim I(d)$, and each component of y_t, denoted as y_{it}, $y_{it} \sim I(d)$;
2. there exists a nonzero column vector β such that $\beta' y_t \sim I(d-b), 0 < b \leq d$

then the components of k-dimensional vector $y_t = (y_{1t}, y_{2t}, \dots, y_{kt})$ are defined to be cointegrated of order (d,b), denoted as $y_t \sim CI(d, b)$. β is called cointegrated vector.

In particular, cointegrated vector is not unique to describe the correlation in between non-stationary variables; cointegrated variables should be integrated of same order; there are k-1 linearly independent cointegrated vectors at most; cointegrated variables have common trend components which are quantitatively proportional.

5.5.2 Cointegration Test

Cointegration tests can be divided into two types according to the test objects: one is cointegration test on the basis of regression residuals, such as cointegration regression Durbin-Watson (CRDW) test, DF test and ADF test; the other one is Johansen test, which will be introduced in this paper, based on regression coefficients.

Cointegration test is not only a method to test whether there exists long-term dependency in between variables, but also a method that can establish a long-term stationary function in between variables. In this chapter we shall only introduce Johansen test. Specific estimation of the cointegration relationship in between variables will be conducted in empirical analysis in next chapter as well as establishment of long-term stationary functions and their effects.

Some non-stationary time series could turn to be stationary after differenced once. These types of time series are defined by economists as time series of I(1). These time series are typically smooth with trends and would not return any certain value. Thus, they reveal discrete on graphs when the samples of these time series of I(1) are unlimited. There is no long-term equilibrium in between these time series.

For a long time, people believed that even though there were trends in time series, these trends were considered to be deterministic, and the nondeterministic parts should fluctuate around the deterministic trends. However, an economic time series of I(1), i.e. a time series with stochastic trends, must be non-stationary. A normal linear regression is meaningless for this type of time series. When two or more time series of I(1) can be linearly combined as a time series of I(0), these time series are called integrated. If variables are integrated, we believe that there is long-term equilibrium in between them and it is meaningful to construct a regression model with these variables.

The basis of cointegration is that time series are integrated of order one. There are mainly two methods of test: one is Engle-Granger two-step method and the other one is Johansen maximum likelihood method. The former is mainly applied to test cointegration in between two variables, whereas the latter allows for testing multiple variables. Hence, we will introduce Johansen test in this paper.

Johansen test was first proposed by Johansen to test cointegration relationships in between variables in VAR models. Johansen used corresponding error correction terms in a VAR model as the basis of Maximum Likelihood Estimation (MLE) method.

Assume that y_t is a $k \times 1$ vector of time series of I(1), then its VAR expression with lag order of p is:

$$y_t = A_1 y_{t-1} + A_2 y_{t-1} + \cdots + A_p y_{t-p} + e_t$$

and the differential form of the above function is:

$$\Delta y_t = \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + \Pi y_{t-1} + e_t$$

where $\Gamma_i = -\sum_{j=i+1}^{p} A_j$ and $\Pi = \sum_{i=1}^{p} A_i - I$. Whether there are cointegration relationships in between variables is dependent on the rank of matrix Π.

There are 3 types of possibilities:

1. the rank of matrix Π, denoted as r, r = 0 indicates that Π is a null matrix. Thus there is no cointegrated vectors in between y_t and in turn no long-term equilibrium.
2. r = n means that Π is a full rank matrix, then y_t is stationary time series.

3. $0 < r < p$, i.e. y_t has r of cointegrated vectors. Thus Π can be decomposed to $\Pi = \alpha\beta'$, where α and β are both $n \times r$ matrixes, α is the coefficient matrix of error correction terms, β is cointegrated vector matrix and r is the number of cointegrated vectors.

5.6 Granger Causality Test

5.6.1 Definition of Granger Causality

Granger causality is a statistical concept of causality that describes causal relationships between variables in econometric models. The main idea that Granger proposed is that if a forecast is better to use histories of both time series x_t and y_t than use y_t alone, then we define that x_t Granger-causes y_t. (Song, Witt & Li 2009)

More formally, x_t does not Granger cause y_t if for all n>0 the mean squared error (MSE) of a forecast of y_{t+n} on the basis of (y_t, y_{t-1}, y_{t-2}…) is the same as the MSE of a forecast of y_{t+n} that uses both (y_t, y_{t-1}, y_{t-2}…) and (x_t, x_{t-1}, x_{t-2}…).

$$\mathrm{MSE}[\mathrm{E}(\hat{y}_t | y_t, y_{t-1}, y_{t-2} \dots] = \mathrm{MSE}[\mathrm{E}(\hat{y}_t | y_t, y_{t-1}, y_{t-2}, \dots, x_t, x_{t-1}, x_{t-2}, \dots]$$

where $\hat{y}_{t+n}$ is the n-period-ahead forecast for y_t. Conversely, x_t Granger-causes y_t.

5.6.2 Granger Causality Test

Essentially, Granger Causality test does not aim to observe "true causality" in between time series, but to identify if one time series precedes another. We firstly take a bivariate test as an example, and then generalize it to a multivariate test by using VAR model.

In a bivariate VAR (p) model,

$$\begin{pmatrix} y_t \\ x_t \end{pmatrix} = \begin{pmatrix} a_{10} \\ a_{20} \end{pmatrix} + \begin{pmatrix} a_{11}^{(1)} & a_{12}^{(1)} \\ a_{21}^{(1)} & a_{22}^{(1)} \end{pmatrix} \begin{pmatrix} y_{t-1} \\ x_{t-1} \end{pmatrix} + \begin{pmatrix} a_{11}^{(2)} & a_{12}^{(2)} \\ a_{21}^{(2)} & a_{22}^{(2)} \end{pmatrix} \begin{pmatrix} y_{t-2} \\ x_{t-2} \end{pmatrix} + \cdots + \begin{pmatrix} a_{11}^{(p)} & a_{12}^{(p)} \\ a_{21}^{(p)} & a_{22}^{(p)} \end{pmatrix} \begin{pmatrix} y_{t-p} \\ x_{t-p} \end{pmatrix} + \begin{pmatrix} e_{1t} \\ e_{2t} \end{pmatrix}$$

If and only if the coefficients $a_{12}^{(q)}$ in coefficient matrixes all equal to zero, we conclude that x_t does not Granger-cause y_t.

The Ganger Causality test is carried out under following hypotheses according to F-statistic.

$$\begin{cases} \text{Null hypothesis } H_0: a_{12}^{(q)} = 0, q = 1,2, \dots, p \\ \text{Alternative hypothesis } H_1: \text{there is at least one q that } a_{12}^{(q)} \neq 0, q = 1,2, \dots, p \end{cases}$$

The F-statistic is

$$S_1 = \frac{(RSS_0 - RSS_1)/p}{RSS_1/(T - 2p - 1)} \sim F(p, T - 2p - 1)$$

where RSS_1 is the Residual Sum of Squares of function y_t in VAR model: $RSS_1 = \sum_{t=1}^{T} \hat{e}_{1t}^2$; RSS_0 is the lagged time series without x_t, i.e. $a_{12}^{(q)} = 0, q = 1,2, \dots, p$,

$$y_t = a_{10} + a_{11}^{(1)} y_{t-1} + a_{11}^{(2)} y_{t-2} + \cdots + a_{11}^{(p)} y_{t-p} + \tilde{e}_{1t}, RSS_0 = \sum_{t=1}^{T} \hat{\tilde{e}}_{1t}^2$$

If S_1 is larger than F critical values, then H_0 is rejected; otherwise, H_0 is accepted, i.e. x_t Granger-causes y_t.

Another factor to be mindful is that Granger Causality test is keenly sensitive to the lag order p, thus comparing the results of AIC and SC, a relatively smaller lag order p will be determined as the optimal lag order.

5.7 Impulse Response Function and Variance Decomposition

In an empirical analysis, impulse response functions demonstrate how the adjustment path of the endogenous variables reflects to shocks or innovations. Since VAR model is a non-theoretic model that needs no apriori constraints to variables, we typically do not analyze how one variable impacts another one, but analyze the reaction of the dynamic system when an error term changes, or in other words, an exogenous impulse occurs. This method is called impulse response function.

According to the aforesaid implication of impulse response function, we can discern that, a variable will be impacted by a shock or an innovation directly. Furthermore, these impacts will also be delivered to other endogenous variables through the dynamic structure in a VAR model. If we take a p-order VAR model VAR (p) as an example,

$$y_t = A_1 y_{t-1} + A_2 y_{t-2} + \cdots + A_p y_{t-p} + e_t$$

where y_t is a $k \times 1$ vector of endogenous variables, A_i is a time-invariant $k \times k$ matrix of coefficients and e_t is a $k \times 1$ vector of error terms. Ω denotes the contemporaneous covariance matrix of error terms herein. Generally, if the above model is reversible, it can also be expressed as a vector moving average model (VMA):

$$y_t = (\psi_0 I + \Psi_1 L + \Psi_2 L^2 + \cdots) e_t$$

where Ψ_i $(i = 0,1,2 \ldots)$ is the matrix of coefficients. Ψ_i can be derived from the matrix of coefficients A_i in the VAR model. The row i, column j element of Ψ_i can be interpreted as the s-period impulse response from the j^{th} variable to the i^{th} variable. This definition is under a precondition that there is only one impulse in the system, in other words, there is no correlation in between the components of error vector e_t.

However, normally this precondition is invalid in practice since e_t is not a standard vector of white noise and Ω is not a diagonal matrix. Therefore, impulse response functions are usually conducted in a transformed VMA model. Because Ω is a positive definite matrix, there should be a non-singular matrix P that satisfies $PP' = \Omega$. The aforementioned VMA model then can be presented as:

$$y_t = \sum_{i=0}^{\infty} (\Psi_i p)(p^{-1} e_{t-i}) = \sum_{i=0}^{\infty} (\Psi_i p)\omega_{t-i}$$

Error vector e_t is replaced by a standard vector of white noise ω_t with the formula transformation above. This model can calculate the impulse response functions from one variable to another one compare the impulse response underlying different lags and determine the impacts of time-delay from one variable to another one.

Impulse response functions are to describe the response caused by shocks from one endogenous variable to another in a VAR model, while variance decomposition aims to further measure the contribution of these shocks against the forecast error variance respectively, that is to say, how much of the forecast error variance can be interpreted by disturbance terms.

Sims (1980) proposed the method of variance decomposition according to VMA (∞) model. His main idea is (Sims 1980):
According to the expression of VMA (∞) model

$$y_t = (\psi_0 I + \Psi_1 L + \Psi_2 L^2 + \cdots) e_t, \qquad t = 1,2,\ldots,T$$

The i^{th} element y_{it} in vector y_t can be expressed as:

$$y_{it} = \sum_{j=1}^{k} \left(c_{ij}^{(0)} e_{jt} + c_{ij}^{(1)} e_{jt-1} + c_{ij}^{(2)} e_{jt-2} + \cdots \right), t = 1,2,\ldots,T, \qquad i = 1,2,\ldots,k$$

where k is the number of variables. Thus the expression in the brackets indicates the sum of the impacts to y_i from the j^{th} error term e_j over the period from the infinite past to the current point in time. Assume that e_j is not serially correlated, thus its variance is:

$$E[\left(c_{ij}^{(0)} e_{jt} + c_{ij}^{(1)} e_{jt-1} + c_{ij}^{(2)} e_{jt-2} + \cdots \right)^2] = \sum_{q=0}^{\infty} \left(c_{jj}^{(q)} \right)^2 \sigma_{jj} \quad i,j = 1,2,\ldots,k$$

In this way, the sum of the impacts to the i^{th} variable from the j^{th} error term over the period from the infinite past to the current point in time can be estimated by variance.

If we assume that the covariance matrix of error vectors is a diagonal matrix, thus the variance of y_t is the simple sum of k terms of aforesaid variances:

$$\operatorname{var}(y_{it}) = \sum_{j=1}^{k} \left\{ \sum_{q=0}^{\infty} \left(c_{jj}^{(q)} \right)^2 \sigma_{jj} \right\} \quad t = 1,2,\ldots,T, \qquad i = 1,2,\ldots,k$$

The variance of y_t can be decomposed into k types of uncorrelated impacts. Hence, in order to estimate the contribution of each of error term relative to y_t, we define a criterion as below:

$$RVC_{j\to i(\infty)} = \frac{\sum_{q=0}^{\infty} \left(c_{jj}^{(q)} \right)^2 \sigma_{jj}}{\operatorname{var}(y_{it})} = \frac{\sum_{q=0}^{\infty} \left(c_{jj}^{(q)} \right)^2 \sigma_{jj}}{\sum_{j=1}^{k} \left\{ \sum_{q=0}^{\infty} \left(c_{jj}^{(q)} \right)^2 \sigma_{jj} \right\}} \quad i,j = 1,2,\ldots,k$$

where RVC is relative variance contribution.

Chapter 6 An Empirical Analysis of the Price Discovery Function in Tanker Forward Freight Agreement Market

6.1 Introduction

As we learn from Chapter 3, the key role of price discovery function is to forecast spot price by forward price. It is also a major indicator to assess the efficiency of price discovery function. Hence, in this paper, the author uses Cointegration Test, Error Correction Model, Granger Causality Test, VAR, Impulse Response Function and Variance Decomposition to analyze the effect of cointegration in between spot market and forward market as well as the lead-lag relationship. The stronger the cointegration relationship in between forward freight rate and spot freight rate is, the better the predictability of forward freight rate is and the more efficient the price discovery function of forward market is.

6.2 Data collection and description

The FFA contracts in tanker market are mainly based on Baltic International Tanker Routes (BITR). However, not all routes have derivatives trade, or rather, the FFA trading in some routes does not perform actively. As shown in Table 4-1 in Chapter 4, TD3 route (Middle Eastern Gulf to Japan) so far has the most active trading of FFA following by TD5 (West Africa to USAC).

Considering the length of the delivery of date of FFA contracts, the author selects the data 1-month FFA prices in TD3 and TD5, which are based on Baltic Freight Assessments, such that there are sufficient data for the construction of forward price series $\{FP\}_t$. Meanwhile, the daily Baltic Dirty Tanker Indices in TD3 and TD5 are selected to simulate the average spot price in these routes. Therefore, the spot price series $\{SP\}_t$ are constructed as well. The aforesaid data were all collected from the database of Baltic Exchange on its website. The dates of the data range from January 1st, 2009 to December 24th, 2012. Weekdays and holidays in this range were excluded. Therefore, there are 997 pairs of data collected for each route, totally 1994 pairs of data.

6.3 An Analysis of the Equilibrium Relationship between Spot Freight Rates and Forward Freight Rates

6.3.1 An Analysis of Correlation between Spot Freight Rates and Forward Freight Rates

In order to be well acquainted with price discovery function in tanker FFA market, the author first analyzes the coefficient of correlation in between spot freight rate series and forward freight rate series. Coefficient of correlation mirrors the degree of the linear correlation in between two series. By calculating the coefficient of correlation between spot freight rate series and forward freight rate series, we could have a rudimentary understanding of the price discovery function of forward prices, and lay a good foundation for the further statistical analysis.

We first observe the trends of these two series in TD3 which are presented in Figure 6-1. Roughly speaking, these two trends are highly correlated, namely, these two series fluctuate basically in the same pace.

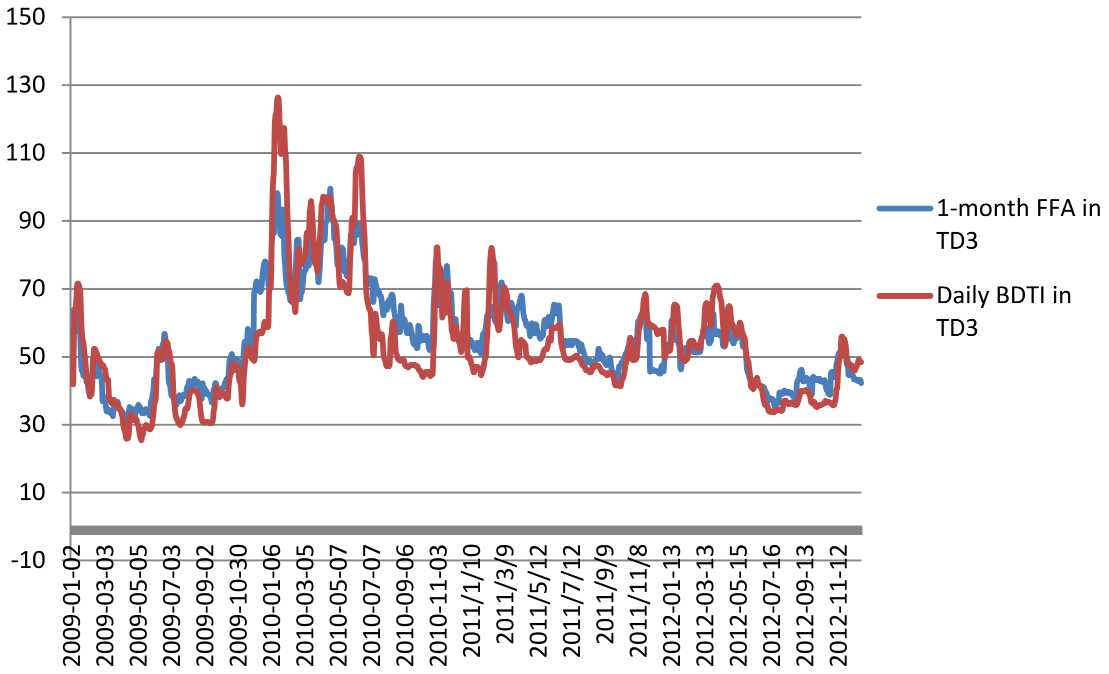

Figure 6-1 Trends of 1-month FFA and daily BDTI in TD3 route
Source: compiled by author

Afterward, the results of the correlation analysis for the collected sample are shown as below:

Table 6-1 Correlation Analysis of Spot Price Series and Forward Price Series in TD3

	Spot Price (SP)	**Forward Price (FP)**
Spot Price (SP)	1.000000	0.895304
Forward Price (FP)	0.895304	1.000000

Source: Compiled by author

The coefficient of correlation between SP and FP is 0.895304, which is very close to 1, in other words, these two series are highly correlated. This preliminarily manifests that the price discovery function of the forward freight rates performs well on forecasting spot prices.

Similar processes are carried out for the sample data in TD5 route. Trends of spot price series and forward price series in TD5, which are presented in Figure 6-2, also reveal synchronicity to a certain extent.

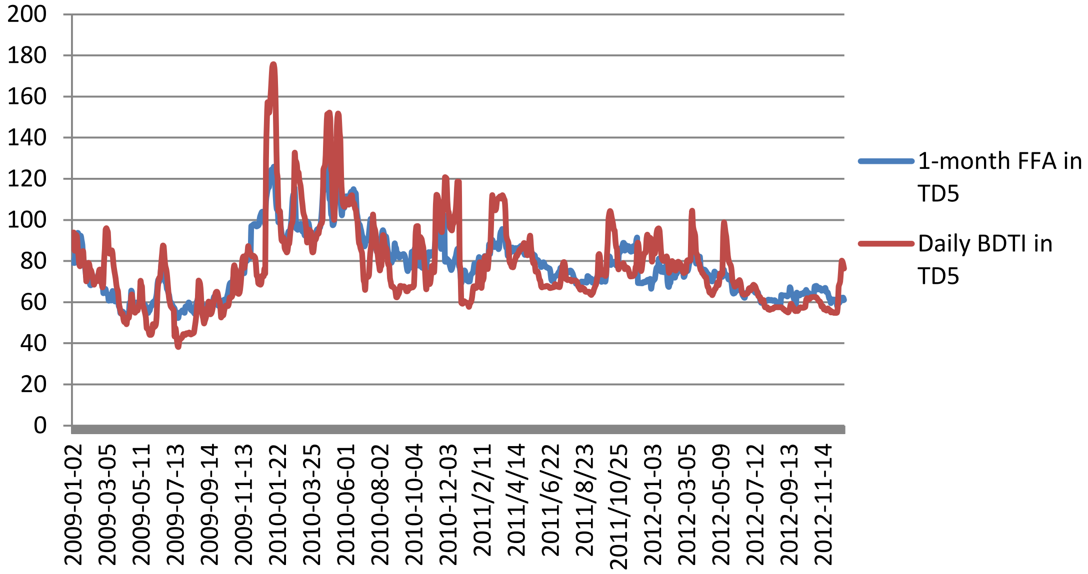

Figure 6-2 Trends of 1-month FFA and daily BDTI in TD5 route
Source: compiled by author

Subsequently, the author calculates the coefficient of correlation of these two series. The results are shown in following table:

Table 6-2 Correlation Analysis of Spot Price Series and Forward Price Series in TD5

	Spot Price (SP)	**Forward Price (FP)**
Spot Price (SP)	1.000000	0.830689
Forward Price (FP)	0.830689	1.000000

Source: Compiled by author

The coefficient of correlation between Spot Price Series and Forward Price Series in TD5 route is 0.830689. Apparently, this is slightly smaller than the coefficient of correlation between the series in TD3. The author conjectured that this difference would be led by the difference of activity of FFA trading to some extent. However, it is still considered to be high enough to mirror the high correlation between Spot Price Series and Forward Price Series in TD5 route. The author drew a similar conclusion with the results in TD3 that the price discovery function of the forward freight rates has good effects on forecasting spot prices.

However, as we know, there always exist spurious correlation relationships between some economic time series, namely, the coefficient of correlation between two series could be relatively high nonetheless these two series are barely correlated. Thus, it is necessary to further test the sample.

6.3.2 Stationarity Test

Considering if there exists cointegration relationship in between spot freight rates and forward freight rates, the author first tested the stationarity of the series in both two routes. As Chapter 3 mentioned, unit root test (ADF test) is adopted to make the analysis. $\{LnSP\}_t$ and $\{LnFP\}_t$ are defined as the logarithmic series of spot prices and the logarithmic series of forward prices respectively. In addition, $\{ILnSP\}_t$ and $\{ILnFP\}_t$ are the first order differenced series of $\{LnSP\}_t$ and $\{LnFP\}_t$ respectively.

The stationarity tests were processed with Eviews. The test results of spot price series in TD3 are shown in table 6-3:

Table 6-3 Stationarity Tests of Spot Price Series and Forward Price Series in TD3

		t-Statistic	**Probability**	**1% level**	**5% level**	**10% level**	**Lag length**
Spot market	$\{SP\}_t$	-0.514369	0.4938	-2.567396	-1.941156	-1.616475	45
	$\{LnSP\}_t$	0.040302	0.6955	-2.567404	-1.941157	-1.616475	48
	$\{ILnSP\}_t$	-10.67014	0.0000	-2.567371	-1.941153	-1.616478	33
Forward market	$\{FP\}_t$	-0.328656	0.5670	-2.567398	-1.941157	-1.616475	46
	$\{LnFP\}_t$	-0.205581	0.6122	-2.567348	-1.941150	-1.616480	26
	$\{ILnFP\}_t$	-7.748374	0.0000	-2.567411	-1.941159	-1.616474	49

Source: compiled by author
Notes:

- Lag length was selected automatic-based on t-statistic, lagpval=0.1, maxlag=60 in EVEWS
- MacKinnon (1996) one-sided p-values

The author discerned from Table 6-3 that the t-statistics of series $\{SP\}_t$ (-0.514369) and $\{LnSP\}_t$ (0.040302) are both larger than the corresponding critical values of 10% significance level (both are -1.616475), namely, there is no sufficient evidence that the null hypotheses could be rejected. Thus the spot price series is non-stationary; it should be first-order differenced and tested again. As the results above revealed, the t-statistic of $\{ILnSP\}_t$ (-10.67014) is smaller than the critical value of 1% significance level of ADF test (-2.567371), the null hypothesis is rejected. Hence, the first-order differenced series $\{ILnSP\}_t$ is stationary.

Similar situations are occurred for the forward price series. The bottom half of Table 6-3 manifest that, as for series $\{FP\}_t$ and $\{LnFP\}_t$ in TD3, the t-statistics (-0.328656 and -0.205581 respectively) are larger than the critical values of 10% significance level (-1.616475 and -1.616480 respectively). Thus there is no sufficient evidence that the null hypothesis could be rejected. The forward price series in TD3 is considered to be non-stationary as well. In contrast, {ILnFP} has a t-statistic of -7.748374, which is much smaller than the 1% significant level critical value of -2.567411. Hence, the first order differenced forward series is stationary as well.

The author repeated the aforementioned ADF tests and analyses on corresponding time series in TD5. Similarly, the spot price series and its logarithmic series in TD5 are first tested. By analyzing the results in Table 6-4, the author found that the t-statistics of spot price series and its logarithmic series in TD5 (-0.640268 and -0.214489 respectively) are larger than the critical values of 10% significance level (-1.616474 and 1.616477 respectively). Hence, there is no sufficient evidence that null hypotheses could be rejected. The spot price series in TD5 is believed as non-stationary. Afterwards, the author tests the $\{ILnSP\}_t$. When looking at the test result in Table 5-4, it is easy to find that the t-statistic of series $\{ILnSP\}_t$ (-10.15528) is much smaller than the critical value of 1% significance level (-2.567396). Likewise, the spot price series in TD5 is first-order stationary.

Finally, the author tests the forward price series in TD5 and presents the results in the lower part of Table 5-4. The t-statistics of series $\{FP\}_t$ and $\{LnFP\}_t$ (-0.423015 and -0.093357 respectively) are larger than the critical values of 10% significance level (-1.616475 and -1.616474 respectively). Thus, the null hypothesis could not be rejected, namely, the forward price series in TD5 is non-stationary. Further the author tests the series $\{ILnFP\}_t$ and then finds that the t-statistic of $\{ILnFP\}_t$ (-9.360607) is far smaller than the critical value of 1% significance level (-2.567396). Hence, the author concluded that the forward price series in TD5 is first-order stationary.

Table 6-4 Stationarity Tests of Spot Price Series and Forward Price Series in TD5

		t-Statistic	**Probability**	**1% level**	**5% level**	**10% level**	**Lag length**
Spot market	$\{SP\}_t$	-0.640268	0.4399	-2.567409	-1.941158	-1.616474	50
	$\{LnSP\}_t$	-0.214489	0.6090	-2.567378	-1.941154	-1.616477	38
	$\{ILnSP\}_t$	-10.15528	0.0000	-2.567396	-1.941156	-1.616475	43
Forward market	$\{FP\}_t$	-0.423015	0.5307	-2.567398	-1.941157	-1.616475	46
	$\{LnFP\}_t$	-0.093357	0.6513	-2.567409	-1.941158	-1.616474	50
	$\{ILnFP\}_t$	-9.360607	0.0000	-2.567396	-1.941156	-1.616475	43

Source: compiled by author
Notes:

- Lag length was selected automatic-based on t-statistic, lagpval=0.1, maxlag=60 in EVEWS
- MacKinnon (1996) one-sided p-values

The results indicated that the spot price series and forward price series are both non-stationary, then what exactly formed this property? Stopford (1997) explained that Freight rates represent the transport costs for cargo owners to shift commodities across various regions around the world. Thus freight rates, which price the value of the shipping service provided by carriers, in turn, determined by the relationship between supply and demand for shipping freight services (Stopford 1997). Kavussanos, Amir and Alizadeh further stated that "*the demand for shipping services is a derived demand, which depends on the economics of commodities transported, world economic activity and the related macroeconomic variables of major economies*" (Kavussanos, Amir & Alizadeh 2001).

The aforesaid macroeconomic variables have been shown to be non-stationary in some literatures. In addition, Kavussanos and Nomikos asserted that "*the cost of transporting different commodities across different parts of the world is affected by oil prices as well as other factors, including inflation. These also have been shown to be non-stationary series. Therefore, the non-stationary nature of the determinants of freight rates may be transmitted to the shipping freight market*" (Kavussanos & Nomikos 2003).

Crude oil as well as other liquid bulk products, as the main energy commodities, is transported around the world. Tanker shipping is regarded as the major mode of transport for those products. Thus the freight rates in tanker market also possess the non-stationary nature of determinants. The results in this section described the non-stationarity in two dirty tanker routes (TD3 and TD5) to a degree, despite that the author could not draw the same conclusion for all tanker routes due to the limitation of data. However, if only looking at these two routes, the probabilities in confidence level for spot prices in TD3 and TD5 are 0.6955 and 0.6090 respectively, which are considered to be very close. Similarly, the probabilities in confidence level for forward prices in these two routes are 0.6122 and 0.6513 respectively. Hence, the author deemed that the price series in these two routes basically perform the same.

6.3.3 Determination of Lag Order P

As the cornerstone of vector autoregressive model, the lag order p should be determined in the beginning. As Section 4.3 introduced, the author will select an optimal order based on both Akaike Information Criterion (AIC) and Schwarz Criterion (SC). The results from these two methods will be compared and then the smaller lag order will be selected as the optimal one. The author summarized the results in Table 6-5 for the series in TD3 and TD5 respectively according to both AIC and SC.

Table 6-5 indicates that, as for series in TD3, lag order 4 has the least value of AIC whilst lag order 2 has the least value of SC. In order to ensure a relatively large degree of freedom for the model, the author selected 2 as the optimal lag order. Similarly, since in the lower half of table 6-5, lag order 3 has the least value of AIC for series in TD5, and lag order 2 has the least value of SC, the author determines 2 as the optimal lag order for the VAR model in TD5 as well.

Table 6-5 Determination of Lag Order in VAR Model for Series in TD3

		Lag order 1	Lag order 2	Lag order 3	Lag order 4	Lag order 5
TD3	AIC	-7.831264	-8.137991	-8.156141	-8.160277	-8.159571
	SC	-7.801628	-8.088598	-8.086992	-8.071371	-8.050907
TD5	AIC	-7.757914	-7.927035	-7.946788	-7.946576	-7.941658
	SC	-7.728279	-7.877643	-7.877638	-7.857669	-7.832995

Source: compiled by author

6.3.4 Cointegration Test

The stationarity tests in Section 5.2.2 prove that the spot price series and forward price in both TD3 and TD5 are all first-order stationary. This satisfies the criteria of cointegration test. In this section, the author introduced Johansen cointegration test to analysis the cointegration relationship in between spot price series and forward price series.

As the results in Section 6.2.3 shown, the lag order p was determined as 2 in both TD3 and TD5 according to both AIC and SC. Hence the author employed Johansen cointegration test for spot price series and forward price series in both TD3 and TD5 and listed the results in Table 6-6.

The author first analyzed the test in TD3. Firstly, the null hypothesis of none cointegrating vector was rejected since the $\lambda_{\max}$ (52.32904) is larger than the critical value (15.89210), whereas the null hypothesis of at most 1 cointegrating vector was not rejected since $\lambda_{\max}$ (9.046942) is smaller than critical value (9.164546). Furthermore, when looking at the trace test, λ_{trace} for the first null hypothesis is 61.37598, which is larger than the critical value (20.26184), thus the hypothesis was rejected. λ_{trace} for the second null hypothesis (9.046942) is smaller than critical value of 9.164546, therefore the hypothesis is not rejected. Hence, the author concluded that there exists 1 cointegrating vector. The cointegration equation could be expressed as:

$$\text{TD3: } e_t = \text{LnFP} - 0.897023\text{LnSP} - 0.444226 \qquad (6\text{-}1)$$

Similarly, the series in TD5 were tested. Apparently, in max-eigen test and trace test, $\lambda_{\max}$ and λ_{trace} for null hypothesis of none cointegrating vector (46.74663 and 54.03826 respectively) are larger than corresponding critical values (15.89210 and 20.26184 respectively). Thus the null hypotheses were both rejected, whereas, as for the null hypotheses of at most 1 cointegrating vector, $\lambda_{\max}$ and λ_{trace} (7.291629 and 7.291629 respectively) are both smaller than the corresponding critical values (both 9.164546). Hence, there is also 1 cointegrating vector for the series in TD5, and the expression of the cointegration equation is:

$$\text{TD5: } e_t = \text{LnFP} - 0.901931\text{LnSP} - 0.435334 \qquad (6\text{-}2)$$

Table 6-6 Johansen Cointegration Test for Spot Price Series and Forward Price Series in Both TD3 and TD5

	Lags	Hypothesis (maximal)		Test statistic	Hypothesis (trace)		Test statistic	95% critical value		Normalized cointegrating coefficients		
		H_0	H_1	λ_{max}	H_0	H_1	λ_{trace}	λ_{max}	λ_{trace}	LnFP	LnSP	C
TD3	2	$r = 0$	$r = 1$	52.32904*	$r = 0$	$r \geq 1$	61.37598*	15.89210	20.26184	1	-0.897023 (0.05063)	-0.444226 (0.19967)
		$r \leq 1$	$r = 2$	9.046942	$r \leq 1$	$r = 2$	9.046942*	9.164546	9.164546			
TD5	2	$r = 0$	$r = 1$	46.74663*	$r = 0$	$r \geq 1$	54.03826	15.89210	20.26184	1	-0.901931 (0.06978)	-0.435334 (0.30180)
		$r \leq 1$	$r = 2$	7.291629	$r \leq 1$	$r = 2$	7.291629	9.164546	9.164546			

Source: compiled by author

Notes:

- Lags were determined in accordance with the results of AIC and SC for a VAR model.
- Figures in parentheses (.) indicate the standard errors of cointegrating coefficients.
- r stands for the amount of cointegrating vectors herein.
- λ_{max} is the Max-Eigen statistic and λ_{trace} is the trace statistic.
- denotes rejection of the hypothesis at the 0.05 level
- The critical values were referenced from MacKinnon-Haug-Michelis (1999) p-values.
- Max-eigenvalue test indicates 1 cointegrating equation at the 0.05 level as well as trace test.
- C represents the constant in cointegrating equations.

6.3.5 Vector Error Correction Model

Engle and Granger combined cointegration and error correction model so as to establish the vector error correction model (VECM). In a vector error correction model, each function represents an error correction model. The error correction terms mirror the long-run equilibrium between variables. With the help of VECM, the speed of dependent variables being drawn to equilibrium along with fluctuation of independent variables could be estimated. VECM can be used to estimate both the short-run and long-run effects of one time series on another (Wikipedia 2013).

In a short-term system, the deviation from equilibrium directly determines the amplitudes of time series. However, the cointegration relationship, from a long-term point of view, could drive the deviated series back to the equilibrium state, while VECMs can exactly indicate the degree of the deviation of the series clearly and reveal the information of the adjustment.

VECMs are constructed on the basis of cointegration relationships in between variables. In addition, Granger proved that there must exist error correction expression if the variables have cointegration relationship. Hence in this paper, the author estimates the impacts to the variation of forward freight rates and spot freight rates caused by long-term trends and short-term effects though VECMs. The results are shown in Table 6-7.

With the results in Table 6-7, VECMs could be constructed. Firstly, the author expressed the two equations of the VECM for spot price series and forward price series in TD3 as follows:

$$\mathrm{TD3:}\ \mathrm{ILnFP_t} = 0.017301\mathrm{ect_{t-1}} + 0.087289\mathrm{ILnFP_{t-1}} + 0.086757\mathrm{ILnSP_{t-1}} - 0.444226 + \mathrm{e_{1t}} \quad (6\text{-}3)$$

$$\mathrm{TD3:}\ \mathrm{ILnSP_t} = 0.066425\mathrm{ect_{t-1}} + 0.087770\mathrm{ILnFP_{t-1}} + 0.440796\mathrm{ILnSP_{t-1}} - 0.444226 + \mathrm{e_{2t}} \quad (6\text{-}4)$$

Likewise, the expressions of two VECM equations in TD5 are listed below:

$$\mathrm{TD5:}\ \mathrm{ILnFP_t} = 0.016808\mathrm{ect_{t-1}} + 0.133903\mathrm{ILnFP_{t-1}} + 0.002879\mathrm{ILnSP_{t-1}} - 0.435334 + \mathrm{e_{1t}} \quad (6\text{-}5)$$

$$\mathrm{TD5:}\ \mathrm{ILnSP_t} = 0.078443\mathrm{ect_{t-1}} + 0.258780\mathrm{ILnFP_{t-1}} + 0.291710\mathrm{ILnSP_{t-1}} - 0.435334 + \mathrm{e_{2t}} \quad (6\text{-}6)$$

So far the construction of VECMs for the spot price series and forward price series in both TD3 and TD5 are accomplished. Next the author will analyze the relationships in between spot freight rates and forward freight rates according to the results above.

First off, when looking at the coefficients in the above 4 formulas, the author noticed that all these coefficients are statistically significant except the coefficient of ect_{t-1} in Formula 6-3. Ect implies the equilibrium relationship between variables whist its coefficient indicates the speed of adjustment when dependent variables deviate from equilibrium in short term. Besides, the coefficients of the independent variables also mirror the impacts on the short-term deviation of dependent variables.

Table 6-7 Results of Vector Error Correction Model

		Error correction term (ect)	$ILnFP_{t-1}$	$ILnSP_{t-1}$	C
TD3	$ILnFP_t$	0.017301	0.087289	0.086757	-0.444226
		(0.01021)	(0.03595)	(0.03260)	(0.19967)
		[1.69457]	[2.42796]	[2.66127]	[-2.22480]
	$ILnSP_t$	0.066425	0.087770	0.440796	-0.444226
		(0.00927)	(0.03263)	(0.02959)	(0.19967)
		[7.16873]	[2.69000]	[14.8985]	[-2.22480]
TD5	$ILnFP_t$	0.016808	0.133903	0.002879	-0.435334
		(0.00721)	(0.03510)	(0.02000)	(0.30180)
		[2.33182]	[3.81474]	[0.14395]	[-1.44245]
	$ILnSP_t$	0.078443	0.258780	0.291710	-0.435334
		(0.01138)	(0.05539)	(0.03156)	(0.30180)
		[6.89596]	[4.67169]	[9.24365]	[-1.44245]

Source: compiled by author

Notes:

- $ILnFP_t$ and $ILnSP_t$ denote the first-order differenced logarithmic series of forward price and spot price respectively.
- C is the constant in VECM.
- (.) indicates the standard error of coefficient.
- [.] represents the t-statistic of coefficient.

Secondly, the author focused on the coefficients of dependent variables. In Formula 6-3, the coefficients of $ILnFP_{t-1}$ and $ILnFP_{t-1}$ (0.087289 and 0.086757 respectively) are very close (the former only slightly larger than the latter), which reveal similar impacts on the forward price at period t. however, as for the coefficients of dependent variables in Formula 6-5 (0.133903 and 0.002879), the author noticed that there exists a significant difference. The author concluded that, the impacts of forward price at period t-1 on forward price at next period are stronger than the impacts from spot price at period t-1. However, these impacts are not significant in route TD3. Similarly, in Formula 6-4 and 6-6, spot price at period t-1 performs better than forward price in the same period on impacting spot price at next period. To have a general comparison, the impacts from forward price to future spot price are stronger than the impacts from spot price to future forward price.

Last but not least, the coefficients of error correction terms ects in these 4 formulas are all positive. In order to describe the process of the adjustment of ect, the author took Formula 6-5 as an example, when $\mathrm{ect} > 0$, it will pose a positive impact on the forward price due to its positive coefficient (0.016808). At the same time, it indicates that the spot price is higher than forward price. On average, the forward price at next period would rise. Therefore, refer to the underestimation of forward price, this negative deviation from equilibrium point at period t-1 will be eliminated. Conversely, when $\mathrm{ect} < 0$, the forward price is considered to be relatively high and it will decrease in next period. Thus overestimated forward price will be adjusted soon so as to eliminate disequilibrium. Overall, the coefficients of ects in Formula 6-3 and 6-5 (0.066425 and 0.078443) are slightly smaller than the coefficients of ects in Formula 6-4 and 6-6 (0.017301 and 0.016808). The author thus asserted that the adjustment speed and extent of error correction terms refer to spot price is larger than the adjustment of ects to forward price. This can be interpreted as spot price relatively deviate larger and more frequently from equilibrium than forward price. Forward price typically could better reflect the supply-demand relationship in market and provide guidance for spot price.

6.4 An Analysis of the Lead-lag Relationship in between Spot Freight Rates and Forward Freight Rates

From the analysis in Section 5.2 we learnt that there exists long-term equilibrium relationship between spot freight rates and forward freight rates. The impacts these two types of freight rates pose on their own are stronger than on each other. Furthermore, the impacts from forward freight rates to spot freight rates are slightly stronger than the reverse impacts. However, these conclusions are not significant. Hence, further analysis need to be taken into account. Whether there is causality between spot freight rates and forward freight rates? Which one leads fluctuations and which one is lag? Which one holds a leading post on generating forward prices? In this section, the author makes deeper analysis to answer these questions.

6.4.1 Granger Causality Test

Granger causality test is mainly used to estimate the lead-lag relationships in between two variables. However, two factors need to be taken into consideration. On the one hand, if the results of the test are sensitive to the lag length, then different lag lengths may lead to different results. Hence, it is necessary to select various lags for the tests. Only if these tests reveal same results, the conclusions made from the results are convincing. On the other hand, the tested series should be stationary.

On the basis of aforementioned factors, the author estimates the lead-lag relationship in between stationary series {$LnSP_t$} and {$LnFP_t$} using Granger causality test with lags of 2. The test results are summarized as below:

Table 6-8 Results of Granger Causality Test of Series in TD3 and TD5

Route	Null hypothesis	Sample size	F-Statistic	Probability
TD3	LnSP does not Granger Cause LnFP	995	5.80752	0.0031
	LnFP does not Granger Cause LnSP	998	29.9528	0.0000
TD5	LnSP does not Granger Cause LnFP	995	2.47107	0.0850
	LnFP does not Granger Cause LnSP	998	33.2988	0.0000

Source: compiled by author

As for series $\{LnSP\}_t$ and $\{LnFP\}_t$ in TD3, the null hypothesis “LnSP does not Granger Cause LnFP” in Granger causality test has a probability of 0.0031. Thus this hypothesis can be rejected underlying 99% confidence level. This indicates that $\{LnSP\}_t$ Granger-causes $\{LnFP\}_t$. Apparently, the other null hypothesis in TD3 (with a probability of 0 due to the F-statistic of 29.9528) is rejected as well. $\{LnFP\}_t$ also Granger-causes $\{LnSP\}_t$. In general, there is bidirectional causal relationship between series $\{LnSP\}_t$ and $\{LnFP\}_t$ in TD3. Considering the probabilities of the null hypothesis in TD3, the leading effects from series $\{LnFP\}_t$ to $\{LnSP\}_t$ is stronger than the converse effects.

However, when observing the results in the lower half the Table 6-8, the author discerned that the probability of the first null hypothesis (0.0850) is considered as relatively large, since only underlying 90% confidence level the null hypothesis can be rejected. Thus, the leading effects from series $\{LnSP\}_t$ to $\{LnFP\}_t$ perform weaklier in TD5 than in TD3. Nonetheless, the leading effects from series $\{LnFP\}_t$ to $\{LnSP\}_t$ in TD5 remain strong underlying the zero probability of null hypothesis (F-statistic is 33.2988, which is the largest one in Table 6-8). This performance is very similar with the series in TD3.

The aforesaid conclusions based on Granger causality tests are just preliminary judgments. Next the author will analyze the specific lead-lag relationships between spot freight rates and forward freight rates on the basis of vector autoregressive models.

6.4.2 Establishment of Vector Autoregression Model

The lag order has been determined in Section 6.2.3. Thus the author could establish VAR(2) models in two routes as below:

Table 6-9 Coefficient Estimation and Test Result of VAR(2) Model in TD3

	LNFP	LNSP
LnFP(-1)	1.094089	0.152221
Std. Error	(0.03488)	(0.03179)
t-Statistic	[31.3647]	[4.78846]
LnFP(-2)	-0.088958	-0.088084
Std. Error	(0.03584)	(0.03266)
t-Statistic	[-2.48214]	[-2.69696]
LnSP(-1)	0.079089	1.382688
Std. Error	(0.03369)	(0.03070)
t-Statistic	[2.34772]	[45.0392]
LnSP(-2)	-0.095601	-0.442459
Std. Error	(0.03263)	(0.02974)
t-Statistic	[-2.92957]	[-14.8781]
C	0.044446	-0.019704
Std. Error	(0.01849)	(0.01685)
t-Statistic	[2.40442]	[-1.16967]

Source: compiled by author

Table 6-10 Coefficient Estimation and Test Result of VAR(2) Model in TD5

	LNFP	LNSP
LnFP(-1)	1.143005	0.336466
Std. Error	(0.03433)	(0.05436)
t-Statistic	[33.2916]	[6.19002]
LnFP(-2)	-0.138821	-0.259263
Std. Error	(0.03508)	(0.05554)
t-Statistic	[-3.95738]	[-4.66827]
LnSP(-1)	-0.008926	1.221289
Std. Error	(0.02021)	(0.03199)
t-Statistic	[-0.44175]	[38.1762]
LnSP(-2)	-0.005509	-0.291968
Std. Error	(0.01998)	(0.03163)
t-Statistic	[-0.27570]	[-9.23002]
C	0.043980	-0.029114
Std. Error	(0.02065)	(0.03269)
t-Statistic	[2.12998]	[-0.89061]

Source: compiled by author

Therefore, the formulas of VAR(2) model in TD3 can be expressed as follows:

$$\mathrm{LnFP_t = 0.044446 + 1.094089LnFP_{t-1} - 0.088958LnFP_{t-2} + 0.079089LnSP_{t-1} - 0.095601LnSP_{t-2} + e_{1,t}} \quad (6\text{-}7)$$

$$\mathrm{LnSP_t = -0.019704 + 0.152221LnFP_{t-1} - 0.088084LnFP_{t-2} + 1.382688LnSP_{t-1} - 0.442459LnSP_{t-2} + e_{2,t}} \quad (6\text{-}8)$$

As for VAR(2) model in TD5, the formulas are:

$$\mathrm{LnFP_t = 0.043980 + 1.143005LnFP_{t-1} - 0.138821LnFP_{t-2} - 0.008926LnSP_{t-1} - 0.005509LnSP_{t-2} + e_{1,t}} \quad (6\text{-}9)$$

$$\mathrm{LnSP_t = -0.029114 + 0.336466LnFP_{t-1} - 0.259263LnFP_{t-2} + 1.221289LnSP_{t-1} - 0.291968LnSP_{t-2} + e_{2,t}} \quad (6\text{-}10)$$

First off, the author analyzed the coefficients in Formula 6-7 and 6-8 respectively. As for series $\{LnFP\}_t$, the impacts from forward price series of last period are significant due to its largest coefficient (1.094089) in the formula. However, the rest series, namely $\{LnFP\}_{t-2}$, $\{LnSP\}_{t-1}$ and $\{LnSP\}_{t-2}$, all have similar slight impacts in accordance with their coefficients (-0.088958, 0.079089 and -0.095601 respectively). Considering coefficients in Formula 6-8 (0.152221, -0.088084, 1.382688 and -0.442459 respectively), $\{LnSP\}_t$ is influenced by the spot price series of last period the most, following by spot price series of the period before last. The other two forward price series perform weakly. In general, in TD3 route, forward price series of last period impact forward prices more significantly than spot price series of last period. So does the spot price series. The coefficients in Formula 6-9 and 6-10 perform basically the same with the coefficients in Formula 6-7 and 6-8. That mainly proves that spot freight rates and forward freight rates generally play similar roles in dirty tanker routes TD3 and TD5.

Furthermore, comparing Formula 6-7 with 6-8 as well as 6-9 with 6-10, the author found that the impacts from forward price series of last period to spot price of current period are stronger than the impacts from spot price series of last period to forward price series of current period. Particularly, these effects reveal more significant in TD5 than in TD3. This conclusion is also the same with the result of VECM in Section 6.2.5. However, it is insufficient to analyze the specific process of the impacts and the extent of the impacts only with VAR model. Hence, next the author will make in-depth analysis of the relationship of information delivery in between spot freight rates and forward freight rates.

6.4.3 Impulse Response Function

In Section 6.3.1 the Granger causality test has proven the causal relationship between spot freight rates and forward freight rates. VAR model further explained the lead-lag relationship between them. In order to find out the specific process how they impact each other, the author introduces Impulse Response Function (IRF). Generally speaking, an impulse response function depicts the responses of endogenous variables to shocks. More specifically, it reflects the impacts on the current and future values of endogenous variables when a standard deviation innovation is added to stochastic disturbance terms. These processes will be illustrated by graphs.

The author analyzed the established VAR models with IRF in a period of 30 days. The following graphs illustrate the impulse response process of VAR model in TD3.

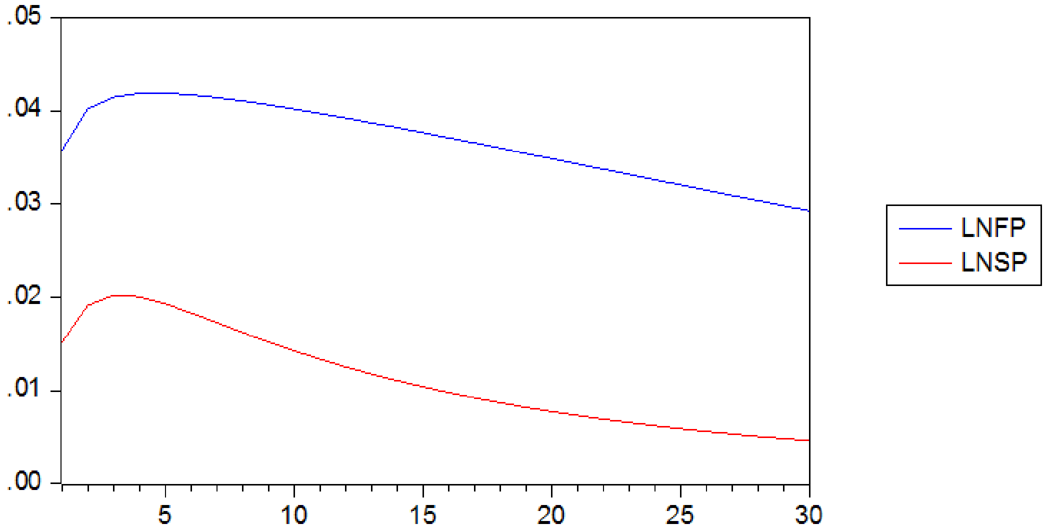

Figure 6-3 Response of LnFP to One S.D. Innovation occurred in LnFP and LnSP respectively in TD3 Route
Source: compiled by author

By observing Figure 6-3, the author discerned that series $\{LnFP\}_t$ responses significantly to the S.D. innovation which first arrived at forward market. At the beginning of the process, $\{LnFP\}_t$ grows for approximately 3.5% and keeps rising in the first 5 days. At the end of the first 5 days, the curve reaches its peak of around 4.2% of growth. Afterwards, the growth rate starts to decline steadily and slightly. When one S.D. innovation first arrived at spot market, $\{LnFP\}_t$ performs relatively weakly, only 1.5% of growth in the beginning. The highest growth rate of around 2% occurs on the third day and then decreases slowly till the end. During the whole process, the impacts from the disturbance on $\{LnFP\}_t$ its own are always larger than the impacts from the disturbance on $\{LnSP\}_t$, notwithstanding their growth rates both tend to return to zero.

The author subsequently analyzed the processes how series $\{LnSP\}_t$ responses to one S.D. innovation shocked in spot market and forward market respectively. The graph of the processes is shown in Figure 6-4.

Similar with $\{LnFP\}_t$ in Figure 6-3, when there is an S.D. innovation shocked spot market, the spot price reacts dramatically at first with a growth rate of around 3.3%. In the first 5 days, the growth rate surges till its highest level of 5.3%. However, in the rest period, the curve slumps to only 1%. In contrast, when an S.D. innovation disturbs $\{LnFP\}_t$ in the beginning, $\{LnSP\}_t$ does not response significantly. It grows by approximately 1.5%. The growth rate soars to 4% in the coming 10 days and then tends to be steady. In the rest 20 days, there is slightly downward trend and finally drops to around 3% of daily growth rate.

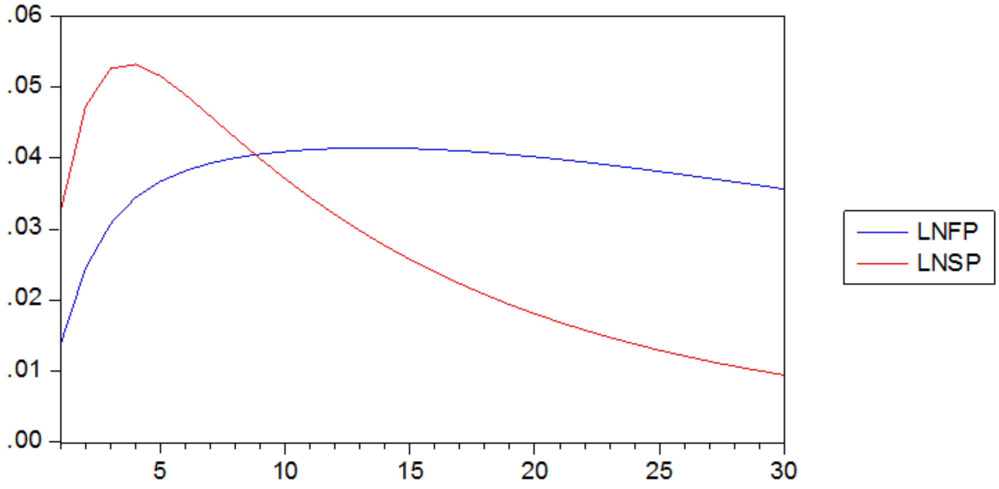

Figure 6-4 Response of LnSP to One S.D. Innovation occurred in LnFP and LnSP respectively in TD3 Route
Source: compiled by author

Comparing these two graphs, the author notices that, on the one hand, the innovation from forward market generates positive impacts on both spot price and forward price. Moreover, the reactions of spot price and forward price both start from a short-term swift growth following by a long-term slow decline. On the other hand, even though the innovation from spot market creates positive impacts, the impacts on both spot price and forward price are relatively weak. Furthermore, the growth rates both have steeper downward trends after the knee points than the growth rates generated by innovations from forward market.

In short, the impulses from the innovation of forward market are stronger than from the innovation of spot market regardless of spot price or forward price. In addition, the impulses to the forward market pose stronger impacts on its own price rather than on the price in the other market. So does the spot market.

Afterwards, the author analyzed how the impulses influence spot market and forward market in TD5 routes. Following graphs depict how $\{LnFP\}_t$ and $\{LnSP\}_t$ response to one S.D. innovation respectively.

Apparently, the shapes of curves in Figure 6-5 and 6-6 are extremely similar with the curves in Figure 6-3 and 6-4. The only difference the author perceived is that the growth incurred by innovations in TD5 route returns to zero more rapidly than the growth in TD3. However, this difference is not significant. Generally speaking, the forward market and spot market have the same inherent characteristics such that they perform typically the same when encountering disturbances of innovations.

To sum up, the author summarizes as follows:

1. Impulses to forward markets generate positive impacts on both forward price and spot price;

2. Impulses to spot markets generate positive impacts on both forward price and spot price;

3. Impulses to forward markets as well as spot markets pose stronger impacts on the prices in their own market rather than the prices in the other market.

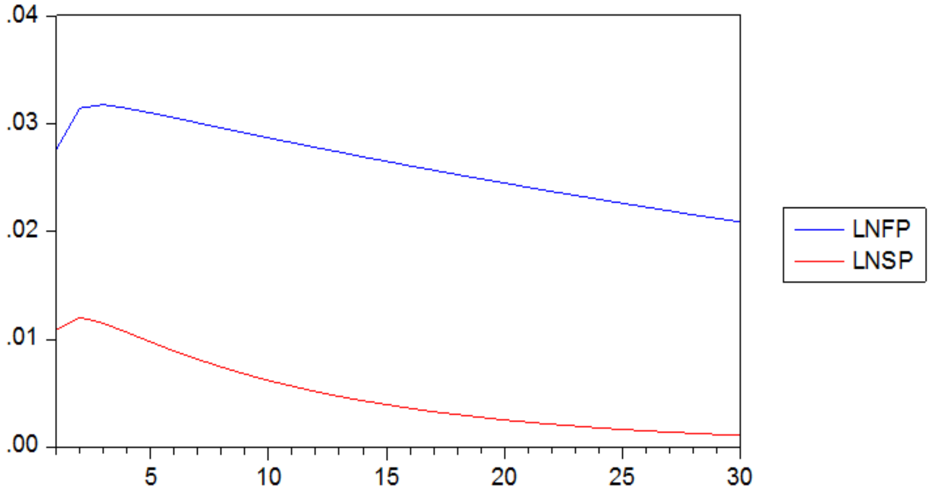

Figure 6-5 Response of LnFP to One S.D. Innovation occurred in LnFP and LnSP respectively in TD5 Route
Source: compiled by author

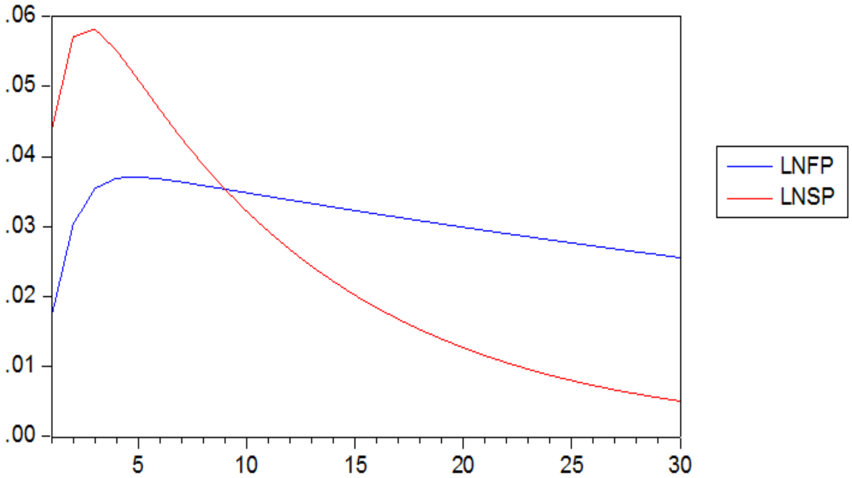

Figure 6-6 Response of LnFP to One S.D. Innovation occurred in LnFP and LnSP respectively in TD5 Route
Source: compiled by author

6.4.4 Variance Decomposition

IRF aims to describe how one S.D. unit of change on one variable impacts the other variables, whilst variance decomposition mirrors the process that the variance of one variable is explained by other variables' variances. In other words, it reflects the contributions of one variable to other variables' variances. The extent of the impacts between spot price and forward price explained by IRF is not significant. Hence, in order to measure the contribution of the spot market and forward market to their own prices, the author introduces variance decomposition in this section.

Table 6-11 Variance Decomposition of Forward Price and Spot Price in TD3

Period	**Variance Decomposition of LnFP**		**Variance Decomposition of LnSP**	
	LnFP (%)	**LnSP (%)**	**LnFP (%)**	**LnSP (%)**
1	100.0000	0.000000	17.89314	82.10686
2	99.81202	0.187982	23.74103	76.25897
3	99.69262	0.307383	28.05399	71.94601
4	99.67231	0.327689	31.78381	68.21619
5	99.70495	0.295046	35.23168	64.76832
6	99.75103	0.248969	38.50152	61.49848
7	99.78726	0.212737	41.62639	58.37361
8	99.80243	0.197571	44.61218	55.38782
9	99.79259	0.207412	47.45486	52.54514
10	99.75778	0.242223	50.14796	49.85204
…	…	…	…	…
30	97.27708	2.722916	76.40122	23.59878
Order of variables in VAR model: LnFP, LnSP				

Source: compiled by author

As we know, the order of variables in the process of variance decomposition determines which variable responses the first to a change in market. Hence this order is critical to the results of variance decomposition. Table 6-11 shows the results of variance decomposition of spot price and forward price in TD3 on the basis of the order of variables (LnFP, LnSP). In this table, the second and the third column list the contributions to forward price from spot market and forward market respectively. Likewise, the last two columns describe these contributions to spot price.

First off, when looking at the second column, the author finds that forward market provides 100% of the contribution to a change in forward price in the lag period of 1 day. In contrast, the contribution of spot market is zero. However, the contributions from these two markets have exactly the opposite trends in the rest lag periods. The contribution from forward market falls continually till 97.27708%, whilst the contribution from spot market keeps on rising to 2.722916%. As for the last two columns, apparently the forward market has provided 17.89314% of contribution to the change of spot price in the very beginning. Moreover, the contribution tends to be increasingly large, over 50% in the lag period of 10 days and reaching 76.40122% in the end. At the same time, the contribution of spot market drops from 82.10686% initially to 23.59878 eventually.

Afterward, the author reversed the order of variables and made the following table.

Table 6-12 Variance Decomposition of Spot Price and Forward Price in TD3

Period	Variance Decomposition of LnFP		Variance Decomposition of LnSP	
	LnFP (%)	LnSP (%)	LnFP (%)	LnSP (%)
1	82.10686	17.89314	0.000000	100.0000
2	79.50473	20.49527	0.730704	99.26930
3	78.32067	21.67933	1.809406	98.19059
4	77.99520	22.00480	3.102507	96.89749
5	78.16379	21.83621	4.589064	95.41094
6	78.60766	21.39234	6.253465	93.74653
7	79.19751	20.80249	8.074324	91.92568
8	79.85683	20.14317	10.02544	89.97456
9	80.54022	19.45978	12.07816	87.92184
10	81.22084	18.77916	14.20352	85.79648
…	…	…	…	…
30	89.12200	10.87800	48.41947	51.58053
Order of variables in VAR model: LnSP, LnFP				

Source: compiled by author

Due to the new order of variables, spot price becomes the first variable to response to a change in market. Therefore, after decomposing the variance of series $\{LnSP\}_t$, the author noticed that only spot market provides the entire contribution in the lag phase of 1 day. However, in the rest lag periods, the contribution of spot market decreases to 51.58053%, whilst the contribution of forward market skyrockets to 48.41947%. Loosely speaking, the trends of contributions herein are very similar with the corresponding contributions in Table 6-11. However, considering the variance decomposition of forward price, the situations become quite different. The contribution of forward market first declines from 82.10686% to 77.99520%, and then starts climbing. The contribution reaches 89.12200% in the lag period of 30 days, even higher than the contribution in the beginning. In contrast, the contribution of spot market undergoes a totally opposite process. It first goes up to 22.00480% from 17.89314% initially, and then falls to 10.87800% in the end.

Taken two tables together, the author noticed that, on the one hand, the spot market contributes far more to the change of forward price in Table 6-12 than the spot market in Table 6-11; one the other hand, the forward market in Table 6-12 contributes much less than the forward market in Table 6-11.

Subsequently, the author summarized the results of variance decomposition of spot price and forward price in TD5 based on both two orders of variables in the following two tables.

Table 6-13 Variance Decomposition of Forward Price and Spot Price in TD5

Period	**Variance Decomposition of LnFP**		**Variance Decomposition of LnSP**	
	LnFP (%)	**LnSP (%)**	**LnFP (%)**	**LnSP (%)**
1	100.0000	0.000000	15.44251	84.55749
2	99.99264	0.007361	23.12965	76.87035
3	99.95379	0.046213	27.97103	72.02897
4	99.87232	0.127680	31.55701	68.44299
5	99.74926	0.250745	34.52712	65.47288
6	99.59049	0.409508	37.15341	62.84659
7	99.40296	0.597041	39.55813	60.44187
8	99.19318	0.806819	41.79869	58.20131
9	98.96685	1.033146	43.90293	56.09707
10	98.72880	1.271198	45.88479	54.11521
…	…	…	…	…
30	94.48772	5.512275	66.64808	33.35192
Order of variables in VAR model: LnFP, LnSP				

Source: compiled by author

Table 6-14 Variance Decomposition of Forward Price and Spot Price in TD5

Period	**Variance Decomposition of LnFP**		**Variance Decomposition of LnSP**	
	LnFP (%)	LnSP (%)	LnFP (%)	LnSP (%)
1	84.55749	15.44251	0.000000	100.0000
2	85.01808	14.98192	1.393483	98.60652
3	85.71078	14.28922	2.935425	97.06458
4	86.47622	13.52378	4.397910	95.60209
5	87.23919	12.76081	5.825475	94.17452
6	87.96674	12.03326	7.259346	92.74065
7	88.64586	11.35414	8.719466	91.28053
8	89.27289	10.72711	10.21153	89.78847
9	89.84852	10.15148	11.73324	88.26676
10	90.37539	9.624606	13.27809	86.72191
…	…	…	…	…
30	95.18595	4.814053	39.15768	60.84232
Order of variables in VAR model: LnSP, LnFP				

Source: compiled by author

It is obvious that in TD5 route, the spot market and forward market perform almost the same with the markets in TD3 route. The only differences are that, not like the fall and rise in table 6-12, the contribution to forward price from forward market only has a upward trend, whilst the contribution of spot market has been decreasing since the lag period of 1 day. Nonetheless, the author still asserted that spot markets and forward markets basically have common functions on impacting spot prices and forward prices.

All in all, the author concluded that:
1. The impacts on forward price from forward market are stronger than from spot market;

2. The impacts on spot price from spot market are stronger than from forward market. However, this difference is not as significant as the difference mentioned in the first statement;

3. The impacts on spot price from forward market are stronger than the impacts on forward price from spot market.

Hence, from a quantitative point of view, forward market plays a more significant role than spot market in price discovery process.

6.5 Conclusion

In this chapter, the author collected the daily BDTI and daily estimated average FFA price in both TD3 route and TD5 route from January 1st, 2009 to December 24th, 2012 to construct spot price series and forward price series respectively. First off, the author used cointegration technique and vector error correction model to analyze the equilibrium relationship between these two series. Afterwards, vector autoregressive models on the basis of Granger causality test are applied to measure to lead-lag relationship and the degree of the impacts of this relationship quantitatively.

Through the aforementioned techniques along with comprehensive analysis, the author concluded as follows:

1. There is long-term equilibrium relationship between spot price and forward price. Whereas this relationship would deviate from equilibrium in short term, and then return to equilibrium rapidly;

2. There is bidirectional causal relationship between these two series. Forward price and spot price both have interpreting abilities to each other. However, the former’s leading effects on the latter is stronger than the reversing effects;

3. There exists interaction between forward market and spot market due to the relationship between forward price and spot price. Nevertheless, the impacts on future spot price from forward market are stronger than the impacts on forward price from spot market;

4. Forward market and spot market impact the future spot price jointly. However, forward market play a more critical role relatively. This can be interpreted as forward market has the price discovery function such that forward price is able to guide spot pirce to a degree.

Chapter 7 Conclusions and Recommendations

7.1 Conclusion

In this paper, the author conducted research with spot prices and forward prices in certain dirty tanker routes as the objects. Tanker spot market and forward market were both analyzed as well as the effects of price discovery function in these markets.

Firstly, a number of relevant literatures were reviewed such that main research thread and methodology were determined. Secondly, as the objects of this paper, tanker freight market and forward freight agreement market were analyzed respectively. Thus, the main characteristics of these two markets were reviewed. Tanker freight market, which regards non-storable shipping service as the main products, is not perfectly competitive and reveals sensitive to various economic political factors. Tanker freight rates are significantly volatile due to various factors such as oil price and oversupply of tanker capacity. In contrast, the product in tanker FFA market is a principal-to-principal derivative contract with underlying non-storable asset of shipping service. FFAs are typically used by market participants to hedge freight risks and speculate. In tanker forward market, price discovery function plays an essential role to guide future spot price. it is believed that there exists lead-lag relationship between spot price and forward price and these two types of price jointly constitute the market price system. On the basis of aforementioned qualitative analyses, the author further collected empirical data to in-depth analysis this lead-lag relationship and the effects of price discovery function.

In order to study the relationship between spot price and forward price in tanker market and the corresponding discovery function, vector autoregressive model was employed. The author selected tanker shipping routes TD3 and TD5 as the objects of VAR model. By means of this method, a number of results were concluded as follows:

1. There is long-term equilibrium relationship between spot price and forward price. Whereas this relationship would deviate from equilibrium in short term, and then return to equilibrium rapidly;

2. There is bidirectional causal relationship between these two series. Forward price and spot price both have interpreting abilities to each other. However, the former's leading effects on the latter is stronger than the reversing effects;

3. There exists interaction between forward market and spot market due to the relationship between forward price and spot price. Nevertheless, the impacts on future spot price from forward market are stronger than the impacts on forward price from spot market;

4. Forward market and spot market impact the future spot price jointly. However, forward market play a more critical role relatively. This can be interpreted as forward market has the price discovery function such that forward price is able to guide spot pirce to a degree.

7.2 Further Reseach Recommendations

Despite a number of research results being obtained refer to the relationship between spot price and forward price in tanker market as well as effects of price discovery function, there still exists some limitations during the process of research. Hence, the author summarized some recommendations against further research as follows:

1. There is only 1-month FFA contract being selected as the object of the research due to the amount and quality of empirical data. It is deemed that if multiple types of FFA contracts could be collect for studying the effects of price discovery function, the research results would be more significant. In particular, the impacts of various settlement periods could be compared. This can provide a better guidance for market participants.

2. FFA is a type of freight derivative, which possesses the basic functions of general financial instruments, namely hedge and speculation. However, the author did not focus on the speculation function of FFA in this paper. Hence, the effects of speculation on the price discovery function of FFA were explained herein.

3. Relevant economic series were not introduced into the research model, thus the price discovery function of spot price in tanker market was not interpreted clearly. This in turn weakened the study of the price discovery function of FFA to a degree.

As mentioned above, a number of limitations appeared in this paper should be taken into account in further researches related to this subject.

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